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FREQUENCY DOMAIN ANALYSIS OF HIGH EXPLOSIVE SIMULATION TECHNIQUE FIDELITY

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The High Explosive Simulation Technique (HEST) is a method of simulating the airblast from a nuclear detonation. HEST cavities are usually designed to match an idealized Speicher-Brode representation of a nuclear airblast overpressure-time waveform, but significant differences often occur. Of particular interest in this report is the high frequency spiking characteristic of HEST cavities and its possible effect upon ground shock and structural response. One product of this work effort was a computer code, FREQRES, which calculates soil or structural response due to an ideal Speicher-Brode airblast waveform input. This response to a Speicher-Brode input can then be compared to the measured HEST response to obtain a qualitative indication of the effects of HEST anomalies. For the test data investigated in this report, the spiking from the HEST records had very little effect upon structural and soil response. FREQRES also provided a quantitative measure of HEST record frequency content transferred to soil and structure response. Keywords:

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PREFACE

The analysis presented herein was performed as part of work conducted during the period May 1984 to September 1984 on Contract DNA 001-82-C-0098, Investigation of Scaling, Simulation, and Associated Requirements for the STP-3 Combined Effects Program.

Conversion factors for U.S. customary to metric (SI) units of measurement.

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	*giga becquerel (GBq)	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$t_K = (t^\circ f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/inch^2 (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 (N-s/m^2)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbs avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/foot^2	kilo pascal (kPa)	4.788 026 X E -2
pound-force/inch^2 (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-foot^2 (moment of inertia)	kilogram-meter^2 (kg·m^2)	4.214 011 X E -2
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	**Gray (Gy)	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials

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SECTION 1

INTRODUCTION

1.1 OBJECTIVE

The main objective of this work was to investigate the effects of high frequency spiking characteristics of the High Explosive Simulation Technique (HEST) upon testbed and test article response. Spiking is the high pressure, high frequency deviation of a HEST loading from a design nuclear airblast waveform. This investigation provided a qualitative and quantitative evaluation of how well the loading from a HEST cavity simulates the idealized airblast overpressure of a nuclear detonation. A secondary objective was to determine how the frequency content of a HEST data record influences measured structure/soil response data.

1.2 BACKGROUND

HEST cavities are designed to match Speicher-Brode representations of airblast overpressure-time waveforms, but significant differences often occur between the recorded data and predictions. Due to the discrete, rather than continuous application of pressure from the det-cord and the numerous reflections which occur within a HEST cavity, a HEST record is strongly characterized by high frequency (greater than 1000 Hz) and sometimes high magnitude pressure spikes. A HEST record can also experience lower frequency, low magnitude deviations from the design

Speicher-Brode pulse[1] but this anomaly is less common. It has long been of concern how these HEST deviations from an ideal airblast time history affect soil media and structure response within a testbed. Is the high frequency content of a HEST record filtered out as the load transfers through soil media and/or a structure? Or does the high frequency input content excite high frequency response modes? These questions are difficult to answer in the time domain. Frequency domain analysis tools such as the Fast Fourier Transform (FFT), Frequency Response Function (FRF), and the inverse FFT are ideal for investigating these questions, and were used in this effort to obtain a qualitative and quantitative determination of HEST fidelity in simulating a Speicher-Brode nuclear environment.

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1. Speicher, S.J. and Brode, H.L., Airblast Overpressure Analytic Expressions for Burst Height, Range and Time--Over an Ideal Surface, PSR Note 385, Pacific-Sierra Research Corp., Los Angeles, CA, November 1981, as modified for time of arrival at high overpressures by memo from S.J. Speicher, Pacific-Sierra Research Corp., 7 June 1982.

SECTION 2

THEORETICAL DEVELOPMENT

2.1 CAUSE-EFFECT RELATIONSHIP

The fundamental assumption in the analysis which follows is that there is a linear cause-effect relationship between two sets of corresponding data records. A linear cause-effect relationship necessarily means that there is an input and an output, related by a linear transfer function (see Figure 1). The input, x(t), may be a HEST overpressure-time waveform, and the output, a(t), may be a soil or structure response-time waveform. Any test data waveform pair, x(t) and a(t), will contain a certain amount of data acquisition system noise. This analysis will ignore the presence of noise and assume that x(t) and a(t) are actual loading and response behavior. This analysis procedure should, therefore, not utilize records containing high levels of noise. Steps should be taken to remove noise content or, if this is not possible, the record should be discarded.

The actual transfer function between an input data record and an output data record may be highly nonlinear. Nonlinearities may result from concrete crushing and cracking, steel yielding, and soil media deforming inelastically, or from undefined soil-silo interactions. However, a linear assumption may be acceptable when investigating changes in output resulting from slight variations in input, such as might be the case when considering the difference between a HEST record and a best-fit

Speicher-Brode nuclear airblast waveform. If there are significant variations between different input data records, the assumed linear transfer function may cause some alterations in output which are erroneous. The amount of variation in the input which can be allowed, without causing significant erroneous alterations in the output, is currently indeterminate.

2.2 FAST FOURIER TRANSFORM

The Fourier transform is a way of representing a time domain function, x(t), in the frequency domain. If $X(\omega)$ is the Fourier transform of x(t), then x(t) and $X(\omega)$ are called a Fourier transform pair.

$$x(t) <=> X(\omega) \tag{1a}$$

$$X(\omega) = \int_{-\infty}^{\infty} x(t)e^{-i\omega t}dt \tag{1b}$$

where t = time (sec)

ω = frequency (rad/sec)

$i = \sqrt{-1}$

If x(t) is a real continuous function of infinite duration, then $X(\omega)$ is a set of complex numbers

$$X(\omega) = a(\omega) + ib(\omega) = [A(\omega)]e^{i\phi(\omega)} \tag{2a}$$

which define both the amplitude and phase associated with each frequency, ω, of the function x(t). The amplitude, A, and phase angle, ϕ, associated with each point of $X(\omega)$ are:

$$A(\omega) = \sqrt{[a(\omega)]^2 + [b(\omega)]^2} = \left|X(\omega)\right| \tag{2b}$$

$$\phi(\omega) = \tan^{-1} \frac{b(\omega)}{a(\omega)} \tag{2c}$$

The amplitudes, A, are all real numbers and the resulting Fourier transform amplitude is a real function which will be referred to as $\left|X(\omega)\right|$.

One time domain function of particular concern is the dc component, which is constant with time (see Figure 2). The Fourier transform of a dc component is a single value at zero frequency, known as a Dirac-delta function. The significance of this Fourier transform pair will be addressed in the next subsection.

The analysis presented in this report utilizes real test data records. These records are of finite duration and are finely digitized sets of points with a constant time step. Therefore, this analysis must use the Discrete Fourier Transform (DFT):

$$X(n/NT) = \frac{1}{N} \sum_{K=0}^{N-1} x(KT)e^{-i2\pi nK/N} \qquad (3)$$

where $x(KT)$ = discrete time series

$K = 0, 1, 2, \ldots, (N-1)$; time domain counter

$n = 0, \pm 1, \pm 2, \ldots$; frequency domain counter

T = time step

N = total number of time steps

$NT = T_0$ = signal duration

The DFT has to be scaled to approximate the continuous integral transform:

$$X_c(n/NT) = T_0 X(n/NT) \qquad (4)$$

where $X_c(n/NT)$ = scaled DFT.

The Fast Fourier Transform (FFT) is a computationally efficient algorithm for calculating the DFT. The FFT algorithm reduces the computation of the DFT of an N point time series from N^2 operations to $N\log_2 N$ operations. If N is fairly large the savings in the number of operations can be very significant. For example, if the number of points in a time series is 4096, Equation (3) requires 16,777,216 operations, while the FFT requires only 49,152.

The number of points in the FFT array is one half the number of points in the original time series. The first FFT value is defined at zero frequency; the second FFT value is defined at the fundamental frequency:

$$f_o = \frac{1}{\text{record duration}} \tag{5}$$

and the third FFT value is defined at twice the fundamental frequency, $2f_o$, and so on. The final FFT value is defined at the Nyquist frequency:

$$f_c = \frac{1}{2(\text{data record time step})} \tag{6}$$

The Nyquist frequency, f_c, should be greater than or equal to the highest frequency of concern in any subsequent analysis.

One further step is application of a "weighting" function or "window" to a discrete time series before it is transformed. It is best that a discrete time series start and end up at zero in order to prevent "leakage" (truncation) effects. Leakage is attenuation in amplitude of the primary frequency component, and magnification of other secondary frequency components. "Weighting" functions or "windows" are used to gradually bring the beginning and end portions of a data trace back to zero. Most test data traces start at zero, but most do not return to zero at the end. For the analysis in this report, a cosine squared spline was applied to the final 15 percent of all data traces to return them to zero.

2.3 INVERSE FAST FOURIER TRANSFORM

The original discrete time series, x(KT), can be reconstructed from the inverse of the DFT.

$$x(KT) = \sum_{n=0}^{N-1} X(n/NT)e^{i2\pi nK/N} \tag{7}$$

Again, an inverse FFT algorithm is used for computational efficiency. The new resultant time series differs slightly from the original time series. As an example, notice the three plots in Figure 3. An original discrete time series is shown in Figure 3a. The FFT amplitude spectrum is shown in Figure 3b and the inverse FFT is shown in Figure 3c. If there were no inaccuracy in the FFT algorithm, the plots in Figures 3a and 3c would be identical. An obvious difference is that the inverse FFT appears to be offset from the time axis. The offset appears to be constant with time, since the final portion of the inverse FFT ends up at the same level as the beginning. A constant offset with time indicates the presence of a dc component in the inverse FFT time history. As was discussed in the previous subsection and shown in Figure 2, a dc component in a time history is caused by the value of the FFT at zero frequency. The FFT in Figure 3b does in fact have a value at zero frequency. But zero frequency is related to an infinite duration in the time domain and the original discrete time series in Figure 3a is of finite duration. Due to the finite time duration, the value of the FFT at zero frequency must be erroneous, and is therefore the reason for the offset in Figure 3c. If the dc component is removed from the inverse FFT, it becomes nearly identical to the original discrete time series (see Figure 4). The inverse FFT removes some of the high frequency spiking present in the original time history due to the reduced number of points defining the new record. The value of the offset is equal to twenty times the value of the full integral of the original discrete time series. The absolute value of the full integral of the original discrete time series is also equal to the value of the FFT amplitude spectrum at zero frequency.

2.4 FREQUENCY RESPONSE FUNCTION

The formulation of a frequency response function (FRF) requires an input-output relationship described in Section 2.1. An FRF is a transfer function in the frequency domain which completely defines the dynamic characteristics of a linear system. Again, using the same nomenclature as was used in Section 2.1, $x(t)$ represents an input time history and $a(t)$ represents an output time history. The Fourier transforms of $x(t)$ and $a(t)$ ($X(\omega)$ and $A(\omega)$, respectively) are a set of complex numbers. The FRF, $H(\omega)$, is simply the Fourier transform of the output divided by the Fourier transform of the input, and is also a set of complex numbers.

$$H(\omega) = A(\omega)/X(\omega) \tag{8}$$

At each individual frequency an FRF describes the output response of a linear system subjected to an input defined by a constant amplitude sine wave of fixed frequency. The input is of the form:

$$x(t) = x_0 \sin \omega t \tag{9}$$

The output response will be a sine wave at the same frequency, ω, fixed amplitude, a_0, and phase difference, ϕ:

$$a(t) = a_0 \sin(\omega t - \phi) \tag{10}$$

From Reference 2:

> Information about the amplitude ratio a_0/x_0 and the phase angle ϕ defines the transmission characteristics or transfer function of the system at the fixed frequency ω. The FRF $H(\omega)$ results if the amplitude ratio and phase angle can be plotted as a function of frequency...
>
> Instead of thinking of amplitude ratio and phase angle as two separate quantities, it has become customary in vibration theory to use a single complex number to represent both quantities. This is $H(\omega)$ which is defined so that its magnitude is equal to the amplitude ratio and the ratio of its imaginary part to its real part is equal to the tangent of the phase angle.

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2. Stearns, S.D., Digital Signal Analysis, Hayden Book Co., Rochelle Park, NJ, 1975.

If

$$H(\omega) = B(\omega) + iC(\omega) \tag{11a}$$

then

$$\left|H(\omega)\right| = \sqrt{B^2 + C^2} = a_0(\omega)/x_0 \tag{11b}$$

$$\phi(\omega) = \tan^{-1} \frac{C}{B} \tag{11c}$$

The FRF amplitude ratio, $\left|H(\omega)\right|$, is a useful tool in determining how much of the HEST pressure records gets through to soil and structural response at a given frequency.

2.5 FOURFIT

Reference 3 discusses the purpose, use and theory of the program FOURFIT. It is basically a program which will examine a HEST pressure record and determine the yield and peak overpressure of a "best-fit" Speicher-Brode ideal nuclear airblast waveform, using frequency domain analysis. The ideal airblast waveform can be substituted for a HEST pressure record as input in order to determine new response data. A listing of FOURFIT is presented in Appendix A with slight modifications for saving the "best-fit" airblast waveform.

2.6 MODIFIED OUTPUT RESPONSE

Since the FRF is a linear transfer function which completely describes the dynamic characteristics of a linear system, varied input waveforms can be applied to the system to get new outputs. As long as changes in the input are relatively minor, the linear assumption remains

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3. Steedman, D.W. and Partch, J.C., FOURFIT--A Computer Code for Determining Equivalent Nuclear Yield and Peak Overpressure by a Fourier Spectrum Fit Method, as yet unpublished DNA report, Applied Research Associates, Inc., Albuquerque, NM, May 1984.

valid (see Section 2.1). Repeating Equation (8) the FRF $H(\omega)$ is defined as:

$$H(\omega) = A(\omega)/X(\omega) \tag{8}$$

Rearranging this equation one obtains:

$$A(\omega) = H(\omega)*X(\omega) \tag{12}$$

The original input time history is $x(t)$. A new input time history $x'(t)$ can be Fourier transformed to obtain $X'(\omega)$. This new Fourier transform can be substituted into Equation (12) to obtain a new output Fourier transform, $A'(\omega)$:

$$A'(\omega) = H(\omega)*X'(\omega) \tag{13}$$

$A'(\omega)$ can be inverse Fourier transformed to obtain a new output response time history, $a'(t)$.

SECTION 3

PROGRAM RESULTS

3.1 PROGRAM FREQRES

Program FREQRES calculates an FRF for a given pair of input and output time histories. Using the defined FRF, the program will calculate a new output time history for any new input time history the user wants to specify. A user's manual for FREQRES is presented in Appendix B, and a listing of the program is presented in Appendix C.

3.2 TEST DATA

Data from a HEST test of a surface flush vertical silo surrounded by soil were analyzed using the program FREQRES. Both the silo and the surrounding soil were loaded by the HEST cavity. The test data had a duration of 49.85 msec and were recorded at a digitizing rate of 200,000 Hz. This resulted in a time step of 5 x 10^{-6} sec, and a total of 9970 digitized points. Figures 5 through 22 present plots of the 18 data records used in this analysis. Table I presents a brief description of each of the plots.

3.3 FOURFIT RESULTS

A FOURFIT analysis was performed on the two HEST pressure time histories, test data record number 2 on the structure and record number 4 on the free field soil. Three plots result from a FOURFIT calculation: (1) a frequency domain plot comparing the FFT of the test data to the FFT of the "best-fit" Speicher-Brode ideal nuclear waveform, (2) a time history comparison of the pressure waveforms, and (3) a time history comparison of the resulting impulse curves. Figures 23a, 23b, and 23c present these three plots for HEST record number 2 on the structure and

Figures 24a, 24b, and 24c present the three plots for HEST record number 4 on the free field soil. The "best-fit" Speicher-Brode ideal nuclear waveform to HEST record number 2 is a 19.08 kt yield surface burst with a peak overpressure of 20,280 psi. For HEST record number 4 it is a 7.83 kt yield surface burst with a peak overpressure of 14,620 psi. The above results indicate substantial variation in the effective yield and peak overpressure across the testbed, and between measurements on the structure and on free field soil.

3.4 FREQUENCY RESPONSE FUNCTIONS

If the system represented by the FRF transfer function is linear, the absolute magnitude of the FRF amplitude ratio has significance. For example, if one specifies a pressure record in psi as an input data record and a velocity time history in in/s as an output data record, then the amplitude ratios of the FRF can be multiplied by a constant ρc (ρ is the density of the material in the linear system and c is the loading wave velocity) to normalize the FRF. In a normalized amplitude ratio FRF, a value of 1.0 at a particular frequency represents perfect transmission of power at that frequency. A value of less than 1.0 represents a decay in power and a value greater than 1.0 represents an amplification of power. In a reinforced concrete silo ρc is fairly constant, and therefore can be used to normalize the FRF. For soil response ρc may vary significantly with depth and time and, therefore, a constant does not exist to normalize the FRF. For other input/output combinations, different constants of proportionality exists. If the input is pressure and the output is strain, then the constant will be a stiffness modulus. If the input is pressure and the output is stress, then no constant of proportionality is

necessary since the input and output are already in the same units and the FRF is already normalized.

Figure 25 shows two FRF's for vertical soil stress response at 0.5 ft and 5.21 ft depths. Notice that at the 0.5' depth, power transmission from the HEST pressure loading to the soil stress response is strong at most frequencies from 0 to 3000 Hz. In fact there is significant power transmission at 1700 Hz, 2200 Hz, and 2800 Hz (relatively high frequencies). The reason for this could be: (1) noise in the data record at the three frequencies mentioned above, or (2) exitation of natural frequencies in response. Notice from Figure 23a that the input power content at frequencies between 1700 Hz and 2800 Hz is very low compared to input power at frequencies less than 100 Hz. Since the HEST contains low power at the higher frequencies, strong power transmission at these frequencies still results in relatively low power for the FFT amplitude spectrum of soil stress response (see Figure 3). Also note from Figure 25 that power transmission at all frequencies greater than 1000 Hz is dramatically reduced when going from the 0.5 ft depth to the 5.21 ft depth. The power transmission between 100 and 1000 Hz is also significantly reduced, but not to the degree evident at higher frequencies. This suggests that by 5 ft depth, the soil has significantly filtered out the high frequency characteristics of the HEST pressure loading.

Figure 26 shows two FRF's for vertical soil velocity response at 5.21 ft and 12.21 ft depths. The FRF at the 5.21 ft depth is very similar in shape to the FRF at the same depth in Figure 25. There is a constant decay in power transmission between 100 Hz and 1000 Hz. At the

12.21 ft depth, power transmission is even further reduced between 100 and 1000 Hz. At this depth power transmission is relatively low at all frequencies above 350 Hz. Soil is a very good attenuator of the high frequency power of a HEST cavity, starting with the higher frequencies.

Figure 27 shows two FRF's for vertical structural velocity response at 0.83 ft and 3.28 ft depths. The FRF amplitude ratio can be normalized through application of the proportionality constant, ρC. Assume the density of concrete to be 4.7 slugs/ft^3 and the loading wave velocity to be 10,000 ft/s.

$$\begin{aligned} \rho C &= (4.7 \text{ slugs/ft}^3)(10{,}000 \text{ ft/s})(\text{ft}^3/1728 \text{ in}^3) \\ &= 27.2 \text{ lb-s/in}^3 \end{aligned} \tag{14}$$

Multiplying this constant times the amplitude ratio scale of 0.0 to 0.03 in Figure 27 results in a normalized scale of 0.0 to 0.82. A noticeable large frequency power transmission (75 percent on the normalized scale) exists at approximately 250 Hz. This is related to the natural frequency of axial response of the vertical cylinder test article. The structure was approximately 21.5 ft in length. At the 0.83 ft depth the time it took the axial stress wave to reach the bottom of the cylinder and reflect back up is (assuming shock wave velocity in concrete = 10,000 ft/s):

$$\frac{2(21.5 \text{ ft} - 0.83 \text{ ft})}{10{,}000 \text{ ft/s}} = 4.13 \times 10^{-3} \text{ sec} \tag{15}$$

The frequency associated with 4.13×10^{-3} sec is $1/4.13 \times 10^{-3}$ sec which equals 242 Hz. At the 3.28 depth the travel time and associated frequency are 3.64×10^{-3} sec and 274 Hz, respectively. The FRF's in Figure 27 also show a decay in power transmission with depth, similar to that for soil response. Comparing Figures 25 and 27, the decay with depth is not as dramatic in the structure as it is in the soil.

The FRF's for structural axial strains and hoop strains (see Figures 28 and 29) show no clear pattern of power transmission decay with depth. This indicates that the structure tends to transmit most of the power from a HEST pressure time waveform over the broad frequency range of 0 to 3000 Hz. The normalizing proportionality constant for structural strains is assumed to be the constrained modulus for concrete, since the concrete in the structure is confined with a high percentage of steel. Assume a constrained modulus of 5.16 x 10^6psi. The strain test data are in units of micro-strain, such that 1 x 10^6 has to be factored out of the proportionality constant. The resulting constant is 5.16. Multiplying this constant times the amplitude ratio scales of 0.0 to 0.8 in Figures 28 and 29 results in a normalized scale of 0.0 to 4.13. A normalized amplitude ratio of 1.0 corresponds approximately to 0.2 on the scales in Figures 28 and 29. There are two characteristics common to both Figures 28 and 29. At the 5.2 ft/5.3 ft depth there is strong power transmission (335 per cent on the normalized scale) at 150-200 Hz. At the 1.3 ft depth there is also strong power transmission (181 percent on the normalized scale) at 1200-1600 Hz. Why the 150-200 Hz strong power transmission is peculiar to the 5.2 ft/5.3 ft depth is currently unclear. The only structural response mode with a natural frequency as low as 150-200 Hz is the axial response of the cylinder associated with the axial stress wave traveling back and forth down the entire length of the cylinder and reflecting off each end. But if this were the cause of the strong frequency power transmission at the 5.2 ft/5.3 ft depth, then it should also occur at the other depths as well. It does not. The 1.3 ft depth in the cylinder occurs in a thick walled portion of the cylinder called the

headworks. Hoop expansion of the cylinder due to passage of the axial compressive wave, and also hoop compression due to large ground shock stresses surrounding the cylinder are very strong near the surface. Hoop expansion and compression are associated with the breathing mode response of a cylinder. The natural frequencies for the breathing mode response of a cylinder are (Ref. 4, pg. 298, Table 12-1):

$$f_i = \frac{\lambda_i}{2\pi R}\left(\frac{E}{\mu(1-\nu^2)}\right)^{1/2} \tag{16}$$

where f_i = ith natural frequency

i = response mode (=0 for breathing mode)

E = Young's Modulus

R = cylinder radius to midsurface

μ = density of shell material

ν = Poisson's ratio

$\lambda_i = (1 + i^2)^{1/2} = 1$ for $i = 0$

The following values are substituted into Equation (16) to determine the lowest breathing mode natural frequency of the headworks:

$i = 0$

$E = 5.77 \times 10^6$ psi (effective Young's Modulus including concrete and steel contributions)

$R = 20.0$ inches

$\mu = 2.25 \times 10^{-4}$ lb s^2/in^4

$\nu = 0.2$

$\lambda_0 = 1$

The result is 1300 Hz. Notice that this falls within the 1200-1600 Hz range of strong power transmission for the 1.3 ft depth in both Figures 28 and 29.

---

4. Blevins, R.D., Formulas for Natural Frequency and Mode Shape, Van Nostrand Reinhold Co., New York, NY, 1979.

3.5 FAST FOURIER TRANSFORM COMPARISONS

Figure 30 shows a comparison of the original FFT amplitude spectrum for test data record number 6 and the FFT amplitude spectrum after the Speicher-Brode waveform influence has been included (see Section 2-6). The FFT with Speicher-Brode influence has higher power at most frequencies between 100 and 3000 Hz. Notice that the same is true when comparing the Speicher-Brode "best-fit" waveform FFT to HEST record number 4 FFT in Figure 24a. In fact the higher power in the Speicher-Brode "best-fit" waveform FFT is the cause of the higher power in the FFT with Speicher-Brode influence in Figure 30. But this higher power has very little effect upon the inverse FFT time history, as will be illustrated in the next section. For test record number 18 which used HEST record number 2 instead of 4 as the input data record in FREQRES, the increased power is only evident above 800 Hz (see Figure 31). Notice that the same is true in Figure 23a in which the fit between 100 and 700 Hz is very good.

3.6 TIME HISTORY COMPARISONS

For records 5 through 20, there is no visible difference between the original record time histories and the response time histories had the surface pressure loading been an ideal Speicher-Brode nuclear waveform. As an example, Figure 32 presents record number 5 and its Speicher-Brode input comparison waveform. The high frequency spiking characteristic of HEST pressure records has negligible effect upon soil and structure response.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

Analysis of the test data presented in this report indicates that the high frequency spiking characteristic of HEST pressure records has negligible effect upon testbed and test article response when compared to loading from a "best-fit" ideal Speicher-Brode nuclear airblast waveform. The high frequency power content of a HEST pressure loading attenuates with depth in both soil and structure. The power decay is more dramatic in soil and is evident in both stress and motion response. Structural strain records show little power transmission decay with depth. This indicates that structural strain response tends to transmit most of the power content of HEST pressure-time waveforms. Beyond the 2000-3000 Hz range the power content in a HEST pressure-time waveform is very low compared to that in the lower frequencies, so that power transmission at the higher frequencies is insignificant.

Strong power transmission is evident in structural response FRF's at natural response mode frequencies. Natural modes are excited by the broad frequency range of power content of a HEST pressure loading, such that the FRF amplitude ratio becomes magnified at the modal frequencies.

The HEST pressure records used in this report (Figures 5 and 6) were very good pressure waveforms, in which the Speicher-Brode "best-fits" from the FOURFIT program matched the pressure and impulse-time waveforms very closely (see Figures 23b, 23c, 24b, 24c). It would be interesting to run this analysis with HEST records from a test which do not provide such good

representations of ideal Speicher-Brode nuclear airblast waveforms. In this case there might be greater variation in output response comparisons. Also, another interesting use of this analysis procedure would be to determine what testbed and test article response would have been, had the HEST loading been exactly as original design. Instead of using the "best-fit" Speicher-Brode waveform to a HEST record, have the FREQRES program read in the original design waveform.

The analysis procedure outlined in this report can be used to investigate the fidelity of any nuclear airblast simulation technique. It is not restricted to HEST.

APPENDIX A

LISTING OF PROGRAM FOURFIT

```
      PROGRAM FOURFIT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     *        TAPE2,TAPE26,TAPE48,TAPE49)
C      ************************************************
C      PROGRAM FOURFIT ESTIMATES THE PEAK OVERPRESSURE
C      AND NUCLEAR YIELD FOR AIRBLAST SIMULATION RECORDS
C      BY COMPARING FITS OF THE DATA FOURIER AMPLITUDE
C      SPECTRUM TO THE FOURIER AMPLITUDE SPECTRA OF TRIAL
C      SPEICHER-BRODES. RESULTS ARE WRITTEN TO A FILE
C      (TAPE48) TO BE READ AND PLOTTED BY PROGRAM FOURPLT.
C      ************************************************
C
C
      COMMON /FFT    / FRQ(3001),AMP(3001),XFFT(3001)
      COMMON /ITERAT/ W(5),P(5),DELTAW(5),DELTAP(5),YLD(5)
      COMMON /THIST / TTIM(6000),PRESS(12000),TIMP(2999),PIMP(2999),
     *                PFILT(6000)
      COMMON /IMP    / IIMP,DTD,DTB,TPEB,DTBN
      COMMON /POINTS/ NEPTS,NBPTS,NI,NEF,NBF
      COMMON /ESTIM / PSOI,WI,PP,W13,PSOF,WF,FS0
      COMMON /PEAK  / DP,TA,PSO,ALPF
      COMMON /SBCONS/ RSKFT,YS,S,XM
      COMMON /FILT  / IFILT,FLO(7),PFDMX(7),PFBMX(7)
      COMMON /PLOTV / ITL(8),ISTL(8),IDB
      COMMON /UNITS / IUNITS,JUNITS
      COMMON /COUNT / ICOUNT,IOPT,LFILT
      COMPLEX XFFT
C
C       TAPE2 CONTAINS INPUT PARAMETERS
C            NEPTS= NO. OF POINTS TO BE READ FROM TAPE
C            IUNITS=1 FOR TAPE INPUT PRESSURE IN PSI
C                  =-1 FOR TAPE INPUT PRESSURE IN MPA
C            JUNITS=1 FOR TAPE INPUT TIME IN MILLISECONDS
C                  =-1 FOR TAPE INPUT IN SECONDS
C            PSOI=INITIAL PEAK OVERPRESSURE ESTIMATE IN MPA
C            WI=INITIAL NUCLEAR YIELD ESTIMATE IN KT
C            IOPT=1: FITTING ROUTINE TO BE DONE
C            IOPT=2: JUST FOURIER TRANSFORM THE DATA
C            IOPT=3: JUST FOURIER TRANSFORM THE SPEICHER-BRODE
C                    DEFINED BY PSOI, WI
C            IFILT=1 FOR FILTER TO BE EXECUTED
C            IFILT=-1 FOR NO FILTER
C            FLO=LOW END CUTOFF FREQUENCY (UP TO 7 ALLOWED)
C            (NOTE:FOR LESS THAN 7 FILTERS, FLO
C            MUST BE SET TO 0. TO ESCAPE THE LOOP.)
C
C
```

```
      REWIND 2
      READ(2,111) NEPTS,IUNITS,JUNITS
      READ(2,112) PSOI,WI
      READ(2,113) IOPT,IFILT
      READ(2,115) (FLO(I),I=1,7)
  111 FORMAT(3I5)
  112 FORMAT(2F5.2)
  113 FORMAT(2I5)
  115 FORMAT(7F10.0)
      WRITE(6,1) PSOI,WI
    1 FORMAT(2X,*PSOI=*,F5.2,5X,*WI=*,F5.2)
      WRITE(48,113) IOPT,IFILT
      ICOUNT=0
      NBPTS=2048
      IF(IOPT.EQ.3) GO TO 7
    3 CALL EBREAD
      IF(IOPT.EQ.2) GO TO 666
    4 CALL FIT
    7 ICOUNT=1
      CALL RANGE
      CALL SPBRODE
  666 END
      SUBROUTINE EBREAD
C      ********************************************
C      THIS SUBROUTINE READS PRESSURE VALUES FROM AN
C      EBCDIC TAPE BASED UPON THE FORMAT PREVIOUSLY
C      USED BY WES.
C      ********************************************
C
C
      COMMON /FFT   / FRQ(3001),AMP(3001),XFFT(3001)
      COMMON /POINTS/ NEPTS,NBPTS,NI,NEF,NBF
      COMMON /THIST / TTIM(6000),PRESS(12000),TIMP(2999),PIMP(2999),
     *                PFILT(6000)
      COMMON /FILT  / IFILT,FLO(7),PFDMX(7),PFBMX(7)
      COMMON /IMP   / IIMP,DTD,DTB,TPEB,DTBN
      COMMON /UNITS / IUNITS,JUNITS
      COMMON /PLOTV / ITL(8),ISTL(8),IDB
      COMMON /COUNT / ICOUNT,IOPT,LFILT
      COMPLEX XFFT
      DIMENSION IWKE(5500),WKE(5500)
      EQUIVALENCE (IWKE(1),WKE(1))
C
C      DELP IS THE DATA BASELINE SHIFT. BE
C      SURE THAT IT IS IN THE PROPER UNITS.
      DIMENSION DUM(3),DA(5)
      DELP=0.0
      REWIND26
C
C      READ TAPE HEADER INFORMATION
```

```
C
      READ(26,30) ITL(3),ITL(4),
     *            DUM(1),DUM(2),
     *            ITL(1),ITL(2),
     *            DTD,NP
   30 FORMAT(3(2A10),E15.8,I5)
      DTD=2.*DTD
      NP=2*NEPTS
C
      ITL(5)=10H PRESSURE
      ITL(6)=10HHISTORY
      ITL(7)=10H
      ITL(8)=10H
      WRITE(48,35) (ITL(L),L=1,8)
   35 FORMAT(8A10)
      DO 20 I=1,NEPTS
          TTIM(I)=0.
          PRESS(I)=0.
   20 CONTINUE
      IF(EOF(26)) 900,901
C
C       SET UP DATA UNITS CONVERSIONS;
C       MSEC TO SEC AND PSI TO MPA.
  901 IF(JUNITS.GE.1) DTD=DTD*.001
      PFACT=.006894757
      IF(IUNITS.LT.0) PFACT=1.
      IP=1
      TIME=0.
      NLINE=NP/5
      RLINE=FLOAT(NP)/5.
      IF(RLINE.GT.NLINE) NLINE=NLINE+1
C
C       READ PRESSURE VALUES
C
      DO 40 J=1,NLINE
         READ(26,50) (DA(JJ),JJ=1,5)
   50    FORMAT(5E16.8)
         IF(EOF(26)) 900,902
  902 DO 60 K=1,5
           P=DA(K)
           PRESS(IP)=(P*PFACT)-DELP
           IP=IP+1
   60    CONTINUE
   40 CONTINUE
      IM=0
      TIME=0.
      DO 11 M=2,NP,2
           IM=IM+1
           TTIM(IM)=TIME
           PRESS(IM)=(PRESS(M)+PRESS(M-1))/2.
```

```
          TIME=TIME+DTD
   11 CONTINUE
C
C      SPLINE THE END OF THE DATA TO ZERO IN
C      CASE OF A TRUNCATED RECORD
      TLAST=TTIM(NEPTS)
      CALL SPLINE(TLAST,NEPTS,TTIM,PRESS)
      PMAX=0.
C
C
C      IF IOPT=1, FIND THE TIME TO DATA
C      PEAK TO AID IN PHASING THE OVERLAYS.
C      AID IN PHASING OVERLAYS
      PMAX=0.
      DO 78 IK=1,NEPTS
           PMAX=AMAX1(PMAX,PRESS(IK))
           IF(PMAX.EQ.PRESS(IK)) TPEB=TTIM(IK)
   78 CONTINUE
C
C
C      REMOVE BASELINE CORRECTION FOR POINTS
C      BEFORE THE ARRIVAL OF THE SHOCK
      DO 77 M=1,NEPTS
           IF(TTIM(M).GT.TPEB) GO TO 990
           PRESS(M)=PRESS(M)+DELP
   77 CONTINUE
C
      GO TO 990
  900 WRITE(6,70)
   70 FORMAT(10X,*END-OF-FILE REACHED EARLY*,///)
  990 CONTINUE
      IF(IOPT.NE.2) GO TO 45
      CALL FMAX(PRESS,NEPTS,YPMN,YPMX)
      CALL FMAX(TTIM,NEPTS,XPMN,XPMX)
      WRITE(48,100) NEPTS,XPMN,XPMX,YPMN,YPMX
      IF(IFILT.LT.0) GO TO 700
C
C      CALL FOR FILTERS TO BE EXECUTED
      CALL FLOOP(TTIM,PRESS,DTD,NEPTS,PFILT)
      RETURN
C
  700 WRITE(48,105) (TTIM(K),K=1,NEPTS)
      WRITE(48,105) (PRESS(KL),KL=1,NEPTS)
  100 FORMAT(I5,4E15.8)
  105 FORMAT(10E15.8)
   45 IIMP=1
C
C      IMPULSE
C
      CALL IMPULSE(IIMP,DTD,NEPTS,NI)
```

```
      IF(IOPT.NE.2) GO TO 110
      ITL(5)=10H IMPULSE H
      ITL(6)=10HISTORY
      WRITE(48,115) ITL(5),ITL(6)
      CALL FMAX(TIMP,NI,XIMN,XIMX)
      CALL FMAX(PIMP,NI,YIMN,YIMX)
      WRITE(48,100) NI,XIMN,XIMX,YIMN,YIMX
      WRITE(48,105) (TIMP(IH),IH=1,NI)
      WRITE(48,105) (PIMP(JH),JH=1,NI)
  115 FORMAT(2A10)
C
C      FIND THE FOURIER TRANSFORM AND CALCULATE AMPLITUDE.
C
  110 TTOT=DTD*NEPTS
C      FREQUENCY INCREMENT
      DFE=1./TTOT
      FQE=0.
C      FOURIER TRANSFORM
      CALL FFTRC(PRESS,NEPTS,XFFT,IWKE,WKE)
      XRE=REAL(XFFT(1))/(2*NEPTS)
      XIE=AIMAG(XFFT(1))/(2*NEPTS)
      FQE=FQE+DFE
      FRQ(1)=FQE
C      AMPLITUDE SPECTRUM
      AMP(1)=SQRT(2.*(XRE*XRE+XIE*XIE))*TTOT
      NEF=NEPTS/2+1
      DO 80 JK=2,NEF
           FQE=FQE+DFE
           FRQ(JK)=FQE
           XRE=REAL(XFFT(JK))/NEPTS
           XIE=AIMAG(XFFT(JK))/NEPTS
           AMP(JK)=SQRT(XRE*XRE+XIE*XIE)*TTOT
   80 CONTINUE
C
      IF(IOPT.NE.2) RETURN
      ITL(5)=10H FOURIER A
      ITL(6)=10HMPLITUDE S
      ITL(7)=10HPECTRUM
      CALL FMAX(FRQ,NEF,XFMN,XFMX)
      CALL FMAX(AMP,NEF,YFMN,YFMX)
      WRITE(48,117) ITL(5),ITL(6),ITL(7)
  117 FORMAT(3A10)
      WRITE(48,100) NEF,XFMN,XFMX,YFMN,YFMX
      WRITE(48,105) (FRQ(LI),LI=1,NEF)
      WRITE(48,105) (AMP(JI),JI=1,NEF)
      RETURN
      END
      SUBROUTINE FIT
C      **********************************************************
C      THIS SUBROUTINE ITERATES ON YIELD WITHIN ITERATIONS ON
```

```
C       PEAK PRESSURE. ITS AIM IS TO REDUCE THE SUM OF THE SQUARES
C       OF THE DIFFERENCE BETWEEN THE DATA AMPLITUDE AT F(I) AND
C       THE ESTIMATED SPEICHER-BRODE AMPLITUDE AT F(I) DIVIDED
C       BY F(I) BASED UPON A TOLERANCE ON PEAK PRESSURE AND YIELD.
C       END RESULT IS A FINAL ESTIMATE OF PEAK OVERPRESSURE
C       (PSOF) AND YIELD (WF). ALSO, AN ESTIMATE OF THE GOODNESS
C       OF FIT (DELL) IS DETERMINED. PRESSURE IS IN MPA,
C       YIELD IS IN KT.
C       ***********************************************************
C
C
      COMMON /POINTS/ NEPTS,NBPTS,NI,NEF,NBF
      COMMON /ESTIM / PSOI,WI,PP,W13,PSOF,WF,FS0
      COMMON /ITERAT/ W(5),P(5),DELTAW(5),DELTAP(5),YLD(5)
      COMMON /FFT   / FRQ(3001),AMP(3001),XFFT(3001)
      COMMON /PEAK  / DP,TA,PSO,ALPF
      DATA TOL/.01/
C
      P(1)=.1*PSOI
      P(2)=.4*PSOI
      P(3)=1.0*PSOI
      P(4)=4.*PSOI
      P(5)=10.*PSOI
      JPRESS=0
C
C       LOOP ON PRESSURE TOLERANCE
C
      DO 100 JJ=1,50
           JPRESS=JPRESS+1
           JMIN=2
           JMAX=4
           IF(JPRESS.NE.1) GO TO 105
           JMIN=1
           JMAX=5
C
C       LOOP ON PRESSURE
C
  105 DO 200 II=JMIN,JMAX
           PP=P(II)
           JYLD=0
           W(1)=0.1*WI
           W(2)=0.4*WI
           W(3)=1.0*WI
           W(4)=4.0*WI
           W(5)=10.*WI
C
C       LOOP ON YIELD TOLERNACE
C
      DO 250 KK=1,50
           JYLD=JYLD+1
```

```
            IMIN=2
            IMAX=4
            IF(JYLD.NE.1) GO TO 255
            IMIN=1
            IMAX=5
C
C       LOOP ON YIELD
C
  255 DO 300 LL=IMIN,IMAX
            W13=W(LL)**.33333
            IF(LL.NE.1) GO TO 256
            CALL RANGE
C
C       DETERMINATION OF RESIDUALS
C
  256 DELTAW(LL)=0.
      DO 350 LK=1,NEF
            FSCL=FRQ(LK)*W13
            IF(FRQ(LK).GT.7000.) GO TO 300
            IF(FSCL.LT.FS0) GO TO 350
            CALL AMPALG(FSCL,BAMP)
            AMPN=ALOG10(AMP(LK))
            BAMPN=ALOG10(BAMP)
            DF2=FRQ(LK)*FRQ(LK)
            DELTAA=(AMPN-BAMPN)/FRQ(LK)
            IF(FRQ(LK).LT.1000.) DELTAA=2.*DELTAA
            IF(FRQ(LK).GT.5000. .AND. FRQ(LK).LT.7000.)
     *          DELTAA=2.*DELTAA
            DELTAA=DELTAA*DELTAA
            DELTAW(LL)=DELTAW(LL)+DELTAA
  350 CONTINUE
  300 CONTINUE
C
C       RESET YIELDS
C
      EPSW=ABS(W(5)-W(1))*2./(W(5)+W(1))
      IF(EPSW.LT.TOL) GO TO 360
      CALL RESETW
  250 CONTINUE
      WRITE(6,1250)
 1250 FORMAT(2X,*FAILED TO CONVERGE ON YIELD*)
      STOP 14
  360 CONTINUE
      DWMIN=AMIN1(DELTAW(1),DELTAW(2),DELTAW(3),DELTAW(4),DELTAW(5))
      DO 365 MM=1,5
            IF(DELTAW(MM).EQ.DWMIN) KW=MM
  365 CONTINUE
      YLD(II)=W(KW)
      DELTAP(II)=DELTAW(KW)
  200 CONTINUE
```

```
C
C      RESET PRESSURES
C
      EPSP=ABS(P(5)-P(1))*2./(P(5)+P(1))
      IF(EPSP.LT.TOL) GO TO 400
      CALL RESETP
  100 CONTINUE
      WRITE(6,1100)
 1100 FORMAT(2X,*FAILED TO CONVERGE ON PEAK PRESSURE*)
      STOP 10
  400 DPMIN=AMIN1(DELTAP(1),DELTAP(2),DELTAP(3),DELTAP(4),DELTAP(5))
      DO 405 NN=1,5
           IF(DELTAP(NN).EQ.DPMIN) KP=NN
  405 CONTINUE
      W13=YLD(KP)**.33333
      PP=P(KP)
      DELL=DELTAP(KP)/NEF
      RETURN
      END
      SUBROUTINE AMPALG(FSCL,BAMP)
C      ***********************************************************
C      THIS SUBROUTINE ESTIMATES THE FOURIER AMPLITUDE OF THE TRIAL
C      PEAK PRESSURE AND YIELD BASED UPON A FIT TO THE SUITE
C      OF NORMALIZED SPEICHER-BRODE FOURIER AMPLITUDE SPECTRA.
C      THE ALGORITHM USES SCALED FREQUENCY OF INTEREST (FSCL),
C      SCALED FUNDAMENTAL FREQUENCY OF THE S-B OF CONCERN (FS0)
C      AND THE PEAK OVERPRESSURE (PP) TO CALCULATE THE SCALED
C      AMPLITUDE. THE ALGORITHM USES PRESSURE IN MPA AND YIELD
C      IN KT. THE EQUATIONS ARE FOR A SURFACE BURST ONLY. THEY ARE
C      VALID FOR ANY YIELD AND FOR PEAK OVERPRESSURE UP TO 100MPA
C      ***********************************************************
C
C
      COMMON /ESTIM/ PSOI,WI,PP,W13,PSOF,WF,FS0
C
      A1=.1788*PP**(-.72)*(FSCL**(-1.*PP**(-.103)))
      A2=.01474*PP**(-.15)*(FSCL/FS0)**(-1.75)
      A3=.0011*PP**(PP**(-.234))*(FSCL/FS0)**(-2.15)
      A4=.00132*FSCL**(-.547)
      A5=.01034*PP**(-.113)*(1./FSCL)*(FSCL/FS0)**(-1.5)
      A6=.000011*PP**.77*(FSCL/FS0)**(-7.5)
      A7=.0000666*PP**.3*(FSCL/FS0)**(-1.5)
      ASCL=A1-A2+A3+A4+A5-A6+A7
      BAMP=ASCL*PP*W13
      RETURN
      END
      SUBROUTINE RESETW
C      ***********************************************
C      THIS SUBROUTINE RESETS THE FIVE YIELD VALUES BASED
C      UPON THIS ITERATION'S MINIMUM RESIDUAL.
```

```
C      ************************************************
C
C
      COMMON /ITERAT/ W(5),P(5),DELTAW(5),DELTAP(5),YLD(5)
C
C      FIND THE MINIMUM DELTA
      IF(DELTAW(5).LT.DELTAW(4)) GO TO 10
      IF(DELTAW(4).LT.DELTAW(3)) GO TO 20
      IF(DELTAW(3).LT.DELTAW(2)) GO TO 30
      IF(DELTAW(2).LT.DELTAW(1)) GO TO 40
C
C      REDEFINE YIELDS BASED UPON THE MINIMUM
C
C      IF DELTAW(1) IS MIN,
      DYLD=(W(2)-W(1))*0.25
      W(5)=W(2)
      DELTAW(5)=DELTAW(2)
      GO TO 50
C
C      IF DELTAW(5) IS THE MINIMUM,
   10 DYLD=(W(5)-W(4))*0.25
      W(1)=W(4)
      DELTAW(1)=DELTAW(4)
      GO TO 50
C
C      IF DELTAW(4) IS THE MINIMUM,
   20 DYLD=(W(5)-W(3))*0.25
      W(1)=W(3)
      DELTAW(1)=DELTAW(3)
      GO TO 50
C
C      IF DELTAW(3) IS THE MINIMUM,
   30 DYLD=(W(4)-W(2))*0.25
      W(1)=W(2)
      W(5)=W(4)
      DELTAW(1)=DELTAW(2)
      DELTAW(5)=DELTAW(4)
      GO TO 50
C
C      IF DELTAW(2) IS THE MINIMUM,
   40 DYLD=(W(3)-W(1))*0.25
      W(5)=W(3)
      DELTAW(5)=DELTAW(3)
   50 W(2)=W(1)+DYLD
      W(3)=W(2)+DYLD
      W(4)=W(3)+DYLD
      RETURN
      END
      SUBROUTINE RESETP
C      ***********************************************
```

```
C       THIS SUBROUTINE RESETS THE FIVE PRESSURE VALUES
C       BASED UPON THIS ITERATION'S MINIMUM RESIDUAL.
C       ********************************************
C
C
      COMMON /ITERAT/ W(5),P(5),DELTAW(5),DELTAP(5),YLD(5)
C
C       FIND THE MINIMUM DELTAP
      IF(DELTAP(5).LT.DELTAP(4)) GO TO 10
      IF(DELTAP(4).LT.DELTAP(3)) GO TO 20
      IF(DELTAP(3).LT.DELTAP(2)) GO TO 30
      IF(DELTAP(2).LT.DELTAP(1)) GO TO 40
C
C       REDEFINE PRESSURES BASED UPON THE MINIMUM
C
C       IF DELTAP(1) IS THE MINIMUM,
      DPRESS=(P(2)-P(1))*0.25
      P(5)=P(2)
      W(5)=W(2)
      DELTAP(5)=DELTAP(2)
      GO TO 50
C
C       IF DELTAP(5) IS THE MINIMUM,
   10 DPRESS=(P(5)-P(4))*.25
      P(1)=P(4)
      W(1)=W(4)
      DELTAP(1)=DELTAP(4)
      GO TO 50
C
C       IF DELTAP(4) IS THE MINIMUM,
   20 DPRESS=(P(5)-P(3))*0.25
      P(1)=P(3)
      W(1)=W(3)
      DELTAP(1)=DELTAP(3)
      GO TO 50
C
C       IF DELTAP(3) IS THE MINIMUM,
   30 DPRESS=(P(4)-P(2))*0.25
      P(1)=P(2)
      W(1)=W(2)
      DELTAP(1)=DELTAP(2)
      P(5)=P(4)
      W(5)=W(4)
      DELTAP(5)=DELTAP(4)
      GO TO 50
C
C       IF DELTAP(2) IS THE MINIMUM,
   40 DPRESS=(P(3)-P(1))*0.25
      P(5)=P(3)
      W(5)=W(3)
```

```
      DELTAP(5)=DELTAP(3)
   50 P(2)=P(1)+DPRESS
      P(3)=P(2)+DPRESS
      P(4)=P(3)+DPRESS
      RETURN
      END
      SUBROUTINE RANGE
C      ************************************************
C      THIS SUBROUTINE IS AN ITERATION TO FIND THE RANGE
C      OF THE ESTIMATED PEAK PRESSURE FOR THE ESTIMATED
C      YIELD. THIS IS NECESSARY FOR COMPUTATION OF THE
C      SPEICHER-BRODE PRESSURE HISTORY, TIME OF ARRIVAL
C      AND POSITIVE PHASE DURATION.
C      ************************************************
C
C
      COMMON /ESTIM / PSOI,WI,PP,W13,PSOF,WF,FS0
      COMMON /PEAK  / DP,TA,PSO,ALPF
      COMMON /SBCONS/ RSKFT,YS,S,XM
      COMMON /COUNT / ICOUNT,IOPT,LFILT
C
C      INITIAL RANGE SPREAD
      IF(IOPT.NE.3) GO TO 78
      PP=PSOI
      W13=WI**.33333
   78 R1=0.01
      R2=0.1
      R3=1.0
      R4=10.
C
C      HOB EQUAL TO ZERO
      Y=0.
      YS1=0.
      YS2=0.
      YS3=0.
      YS4=0.
      DO 100 I=1,1000
           RS1=R1/W13
           RS2=R2/W13
           RS3=R3/W13
           RS4=R4/W13
C
C      CALCULATE PSO FOR EACH TRIAL SCALED RANGE
           CALL PPEAK(RS1,YS1,P1)
           DP1=DP
           CALL PPEAK(RS2,YS2,P2)
           DP2=DP
           CALL PPEAK(RS3,YS3,P3)
           DP3=DP
           CALL PPEAK(RS4,YS4,P4)
```

```
            DP4=DP
C
C        FIND BOUNDING RANGES
            IF(PP.GT.P2 .AND. PP.LT.P1) GO TO 110
            IF(PP.GT.P3 .AND. PP.LT.P2) GO TO 120
            IF(PP.GT.P4 .AND. PP.LT.P3) GO TO 130
      WRITE(6,1140)
 1140 FORMAT(2X,*PRESSURE OUT OF RANGE*)
      STOP11
C
C        BETWEEN R1 AND R2
  110       DR=(R2-R1)/3.
            R4=R2
            R2=R1+DR
            R3=R2+DR
            GO TO 99
C
C        BETWEEN R2 AND R3
  120       DR=(R3-R2)/3.
            R1=R2
            R4=R3
            R2=R1+DR
            R3=R2+DR
            GO TO 99
C
C        BETWEEN R3 AND R4
  130       DR=(R4-R3)/3.
            R1=R3
            R2=R1+DR
            R3=R2+DR
   99       IF((R4-R1).LE..0001) GO TO 101
  100 CONTINUE
      WRITE(6,1100)
 1100 FORMAT(2X,*FAILED TO CONVERGE ON RANGE*)
      WRITE(6,1200) I
 1200 FORMAT(2X,*I=*,I5)
      WRITE(6,1201) PP,R1,R4
 1201 FORMAT(2X,*PP=*,E12.5,/,2X,*R1=*,E12.5,/,2X,*R4=*,E12.5)
      STOP12
  101 RAKFT=(R1+R2+R3+R4)*0.25
      RSKFT=RAKFT/W13
      DP=(DP1+DP2+DP3+DP4)*0.25
      FS0=1./(DP/1000.)
      IF(ICOUNT.NE.1) GO TO 103
      TASEC=(TA/1000.)*W13
      DPOS=(DP/1000.)*W13
      RANKM=RAKFT*.3048
      PSOF=PP
      WF=W13*W13*W13
C
```

```
C      WRITE FINAL RESULTS TO OUTPUT FILE
      WRITE(6,1102)PSOF,WF,RANKM,TASEC,DPOS
 1102 FORMAT(//,1X,*++++++++++++++++++++++++++++++++++++++++++++++++*,/,
     *       2X,*PEAK OVERPRESSURE,MPA=*,6X,E12.5,//,
     *       2X,*NUCLEAR YIELD,KT=*,11X,E12.5,//,
     *       2X,*RANGE FROM GZ,KM=*,11X,E12.5,//,
     *       2X,*TIME OF ARRIVAL,SEC=*,8X,E12.5,//,
     *       2X,*POSITIVE PHASE DURATION,SEC=*,E12.5,/,1X,
     *       *++++++++++++++++++++++++++++++++++++++++++*,//)
C
      WRITE(48,1103) PSOF,WF
      WRITE(48,1104) DP,TA,RSKFT
 1103 FORMAT(2E15.8)
 1104 FORMAT(3E15.8)
  103 RETURN
      END
      SUBROUTINE PPEAK(X,Y,PEAKP)
C      **********************************************************
C      THIS SUBROUTINE CALCULATES THE PEAK OVERPRESSURE (MPA),
C      TIME OF ARRIVAL (TA,MS/KT**1/3), AND POSITIVE PHASE
C      DURATION (DP,MS/KT**1/3) AFTER SPEICHER-BRODE, JUNE, 1982.
C      **********************************************************
C
C
      COMMON /PEAK  / DP,TA,PSO,ALPF
      COMMON /SBCONS/ RSKFT,YS,S,XM
C
      XLEAST=1.E-9
      YLEAST=1.E-9
      ZMAX=100.
      IF(X.LT.XLEAST) X=XLEAST
      IF(Y.LT.YLEAST) Y=YLEAST
      R=SQRT(X*X+Y*Y)
      R2=R*R
      R3=R*R2
      R4=R2*R2
      R6=R2*R4
      R8=R4*R4
      Z=Y/X
      Z2=Z*Z
      Z3=Z*Z2
      Z5=Z2*Z3
      Z17=Z**17.
      Z18=Z**18.
      Y7=Y**7.
      IF(Z.GT.ZMAX) Z=ZMAX
      XM=170.*Y/(1.+337.*Y**.25)+.914*Y**2.5
C
C      SCALED TIME OF ARRIVAL
C
```

```
      U1=(.543-21.8*R+386.*R2+2383.*R3)*R8
      U2=2.99E-14-1.91E-10*R2+1.032E-6*R4-4.43E-6*R6
      U3=(1.028+2.087*R+2.69*R2)*R8
      UTA=U1/(U2+U3)
      TA=UTA
      IF(X.LT.XM) GO TO 101
      W1=(1.086-34.605*R+486.3*R2+2383.*R3)*R8
      W2=3.0137E-13-1.2128E-9*R2+4.128E-6*R4-1.116E-5*R6
      W3=(1.632+2.629*R+2.69*R2)*R8
      WTA=W1/(W2+W3)
      TA=UTA*XM/X+WTA*(1.-XM/X)
C
C      SCALED POSITIVE PHASE DURATION
C
  101 S=1.-1.1E10*Y7/(1.+1.1E10*Y7)-(2.441E-8*Y*Y/
     *   (1.+9.E10*Y7))*(1./(4.41E-11+X**10.))
      DP=((1640700.+24629.*TA+416.15*TA*TA)/
     *    (10880.+619.76*TA+TA*TA))
     *    *(.4+.001204*(TA**1.5)/(1.+.001559*TA**1.5)+
     *    (.0426+.5486*(TA**.25)/(1.+.00357*TA**1.5))*S)
C
      AA=1.22-(3.908*Z2)/(1.+810.2*Z5)
      BB=2.321+(Z18/(1.+1.113*Z18))*6.195-(.03831*Z17)/
     *    (1.+.02415*Z17)+.6692/(1.+4164.*Z**8.)
      CC=4.153-(1.149*Z18)/(1.+1.641*Z18)-1.1/(1.+2.771*Z**2.5)
      DD=-4.166+(25.76*Z**1.75)/(1.+1.382*Z18)+8.257*Z/(1.+3.219*Z)
      EE=1.-(.004642*Z18)/(1.+.003886*Z18)
      FF=.6096+(2.879*Z**9.25)/(1.+2.359*Z**14.5)-17.15*Z2/
     *    (1.+71.66*Z3)
      GG=1.83+5.361*Z2/(1.+.3139*Z**6.)
      HH=-(64.67*Z5+.2905)/(1.+441.5*Z5)-1.389*Z/(1.+49.03*Z5)+
     *    (8.808*Z**1.5)/(1.+154.5*Z**3.5)+(.0014*R2/(1.-.158*R+
     *    .0486*R**1.5+.00128*R2))*(1./(1.+2.*Y))
C
C      PEAK OVERPRESSURE
      P0=10.47/(R**AA)+BB/(R**CC)+DD*EE/(1.+FF*R**GG)+HH
      PEAKP=P0*.006894757
      RETURN
      END
      SUBROUTINE SPBRODE
C      ******************************************************
C      THIS SUBROUTINE CALCULATES THE PRESSURE HISTORY FOR
C      THE FINAL PRESSURE-YIELD PAIR DETERMINED BY SUBROUTINE
C      FIT. IT USES THE SPEICHER-BRODE JUNE,1982 ALGORITHM.
C      ******************************************************
C
C
      COMMON /THIST / TTIM(6000),PRESS(12000),TIMP(2999),PIMP(2999),
     *                PFILT(6000)
      COMMON /FFT   / FRQ(3001),AMP(3001),XFFT(3001)
```

```
      COMMON /ESTIM / PSOI,WI,PP,W13,PSOF,WF,FS0
      COMMON /PEAK  / DP,TA,PSO,ALPF
      COMMON /FILT  / IFILT,FLO(7),PFDMX(7),PFBMX(7)
      COMMON /SBCONS/ RSKFT,YS,S,XM
      COMMON /POINTS/ NEPTS,NBPTS,NI,NEF,NBF
      COMMON /IMP   / IIMP,DTD,DTB,TPEB,DTBN
      COMMON /COUNT / ICOUNT,IOPT,LFILT
      COMMON /PLOTV / ITL(8),ISTL(8),IDB
      COMPLEX XFFT
      DIMENSION IWKB(11)
      DATA JCOUNT/0/
C
      IF(IOPT.NE.3) GO TO 5
      ITL(1)=10HCALCULATED
      ITL(2)=10H SPEICHER
      ITL(3)=10HBRODE PRES
      ITL(4)=10HSURE HISTO
      ITL(5)=10HRY
      ITL(6)=10H
      ITL(7)=10H
      ITL(8)=10H
      WRITE(48,26) (ITL(IO),IO=1,8)
   26 FORMAT(8A10)
C
C      CALCULATE SPEICHER-BRODE TIMESTEP BASED
C      UPON THE POSITIVE PHASE DURATION.
      DTB=DP/NBPTS
      GO TO 15
    5 ISTL(1)=10HWITH FOURF
      ISTL(2)=10HIT SPEICHE
      ISTL(3)=10HR BRODE
      ISTL(4)=10H
      ISTL(5)=10H
      ISTL(6)=10H
      ISTL(7)=10H
      ISTL(8)=10H
      WRITE(48,26) (ISTL(IG),IG=1,8)
      CALL FMAX(PRESS,NEPTS,YPMN,YPMX)
      CALL FMAX(TTIM,NEPTS,XPMN,XPMX)
      WRITE(48,200) NEPTS,XPMN,XPMX,YPMN,YPMX
      WRITE(48,210) (TTIM(IU),IU=1,NEPTS)
      WRITE(48,210) (PRESS(IP),IP=1,NEPTS)
  200 FORMAT(I5,4E15.8)
  210 FORMAT(10E15.8)
      ICOUNT=0
C
C      FIND THE PEAKS OF THE LOW PASS
C      FILTERED DATA PRESSURE HISTORIES
      DO 7 I=1,7
           CALL FILTER(DTD,NEPTS)
```

```
          CALL FMAX(PFILT,NEPTS,PFDMN,PFDMX(I))
    7 CONTINUE
      ICOUNT=1
C
C      CALCULATE SPEICHER-BRODE TIME STEP BASED
C      UPON THE DATA TIME STEP FOR FILTERING
      DTB=DTD*1000./W13
C
C      CALCULATE THE SPEICHER-BRODE TIME STEP BASED
C      UPON THE POSITIVE PHASE DURATION FOR OVERLAYS
   35 IF(JCOUNT.EQ.1) DTB=DP/NBPTS
   15 DO 25 KJ=1,NBPTS
          TTIM(KJ)=0.
          PRESS(KJ)=0.
   25 CONTINUE
      X=RSKFT
      TF=TA+DP
      P0=PSOF*145.038
      F=(.01477*(TA**.75)/(1.+.005836*TA)+7.402E-5*(TA**2.5)/
     *  (1.+1.429E-8*TA**4.75)-.216)*S+.7076-3.077E-5*
     *  TA*TA*TA/(1.+4.367E-5*TA*TA*TA)
      G=10.+(77.58-64.99*(TA**.125)/(1.+.04348*SQRT(TA)))*S
      H=2.753+.05601*TA/(1.+1.473E-9*TA**5.)+(.01769*TA/
     *  (1.+3.207E-10*TA**4.25)-.03209*(TA**1.25)/(1.+9.914E-8*
     *  TA**4.)-1.6)*S
C
C       CALCULATE PRESSURE HISTORY
C
      DO 400 J=1,NBPTS
          T=TA+(J-2)*DTB
C      SAVE UNSCALED TIMES
          TTIM(J)=T*W13/1000.
          PRESS(J)=0.
          IF(T.LT.TA) GO TO 400
          IF(T.GT.TF) GO TO 410
          B=(F*(TA/T)**G+(1.-F)*(TA/T)**H)*(1.-(T-TA)/DP)
          XE=3.039*Y/(1.+6.7*Y)
          E=ABS((X-XM)/(XE-XM))
          IF(E.GT.50.) E=50.
          D=.23+583000.*Y*Y/(26667.+1.E6*Y*Y)+.27*E+(.5-583000.*Y*Y/
     *      (26667.+1.E6*Y*Y))*E**5.
          A=(D-1.)*(1.-(E**20.)/(1.+(E**20.)))
          DT=474.2*Y*(X-XM)**1.25
          IF(DT.LT.1.E-9) DT=1.E-9
          GA=(T-TA)/DT
          IF(GA.GT.400.) GA=400.
          V=1.+(3.28E11*(Y**6.)/(1.+1.5E12*Y**6.75))*(GA*GA*GA/
     *      (6.13+GA*GA*GA))*(1./(1.+9.23*E*E))
          C=((1.04-240.9*(X**4)/(1.+231.7*X**4))*(GA**7)/
     *      ((1.+.923*GA**8.5)*(1.+A)))*(1.-((T-TA)/DP)**8.)
```

```
     *        *2.3E13*Y**9./(1.+2.3E13*Y**9)
              POFT=P0*(1.+A)*(B*V+C)
              IF(X.LT.XM. OR .Y.GT..38) POFT=P0*B
              PRESS(J)=POFT/145.
  400 CONTINUE
C
  410 JCOUNT=JCOUNT+1
C
C        UNSCALE THE SPEICHER-BRODE TIMESTEP
      DTBN=DTB*W13/1000.
      IF(JCOUNT.GT.1 .OR. IOPT.EQ.3) GO TO 900
C
C        FIND THE PEAKS OF THE LOW PASS FILTERED
C        SPEICHER-BRODE PRESSURE HISTORIES
      LFILT=0
      DO 17 J=1,7
           CALL FILTER(DTBN,NBPTS)
           CALL FMAX(PFILT,NBPTS,PFBMN,PFBMX(J))
   17 CONTINUE
C
C        FIND THE LOW PASS FIDELITY FREQUENCY
C
      DO 27 K=1,7
           PFMAX=PFDMX(K)*0.90
           IF(PFMAX.LE.PFBMX(K)) GO TO 47
   27 CONTINUE
      WRITE(6,37)
   37 FORMAT(2X,*++++ FAILED TO LOCATE LOW PASS FIDELITY ++++*)
      ALPF=-999.
      WRITE(48,57) ALPF
      GO TO 35
   47 ALPF=FLO(K)
      WRITE(48,57) ALPF
   57 FORMAT(F10.0)
      WRITE(6,67) ALPF
   67 FORMAT(2X,*++++ LOW PASS FIDELITY (HZ) = *,F10.0,* ++++*)
      IF(JCOUNT.EQ.1) GO TO 35
C
C        DETERMINE NUMBER OF SPEICHER BRODE PAIRS TO
C        BE PLOTTED FOR OVERLAY
  900 TE=NEPTS*DTD
      NPPTS=IFIX(TE/DTBN)
      IF(IOPT.EQ.3) NPPTS=NBPTS
      WRITE(48,450) NPPTS
  450 FORMAT(I5)
      IF(IOPT.EQ.3) GO TO 810
C
C        AFFECT A TIME SHIFT IN SPEICHER-BRODE HISTORY
C        TO ALLOW THE OVERLAY TO BE PROPERLY PHASED
      TSHFT=(TA*W13/1000.)-TPEB
```

```
      DO 800 JT=1,NBPTS
           TTIM(JT)=TTIM(JT)-TSHFT
  800 CONTINUE
C
      GO TO 130
  810 CALL FMAX(TTIM,NBPTS,XPMN,XPMX)
      CALL FMAX(PRESS,NBPTS,YPMN,YPMX)
      WRITE(48,840) XPMN,XPMX,YPMN,YPMX
  840 FORMAT(4E15.8)
      IF(IFILT.LT.0) GO TO 130
C
C      CALL FOR FILTERS TO BE EXECUTED
      CALL FLOOP(TTIM,PRESS,DTBN,NBPTS,PFILT)
      RETURN
  130 WRITE(48,210) (TTIM(IJ),IJ=1,NPPTS)
      WRITE(48,210) (PRESS(JI),JI=1,NPPTS)
      WRITE(49,200) NPPTS,DTBN
      WRITE(49,210) (TTIM(IJ),IJ=1,NPPTS)
      WRITE(49,210) (PRESS(JI),JI=1,NPPTS)
      IF(IOPT.EQ.3) GO TO 850
C
C      IMPULSE
C
  135 ITL(5)=10H IMPULSE H
      ITL(6)=10HISTORY
      WRITE(48,215) ITL(5),ITL(6)
  215 FORMAT(2A10)
      CALL FMAX(TIMP,NI,XIMN,XIMX)
      CALL FMAX(PIMP,NI,YIMN,YIMX)
      WRITE(48,200) NI,XIMN,XIMX,YIMN,YIMX
      WRITE(48,210) (TIMP(IY),IY=1,NI)
      WRITE(48,210) (PIMP(IT),IT=1,NI)
  850 IIMP=2
      CALL IMPULSE(IIMP,DTBN,NPPTS,NI)
      WRITE(48,450) NI
      IF (IOPT.NE.3) GO TO 150
      ITL(3)=10HBRODE IMPU
      ITL(4)=10HLSE HISTOR
      ITL(5)=10HY
      WRITE(48,225) ITL(3),ITL(4),ITL(5)
  225 FORMAT(3A10)
      CALL FMAX(TIMP,NI,XIMN,XIMX)
      CALL FMAX(PIMP,NI,YIMN,YIMX)
      WRITE(48,840) XIMN,XIMX,YIMN,YIMX
  150 WRITE(48,210) (TIMP(KJ),KJ=1,NI)
      WRITE(48,210) (PIMP(KL),KL=1,NI)
      IF(IOPT.NE.1) GO TO 175
C
C      FIND THE FOURIER TRANSFORM AND CALCULATE AMPLITUDE.
C
```

```
      ITL(5)=10H FOURIER A
      ITL(6)=10HMPLITUDE S
      ITL(7)=10HPECTRUM
      WRITE(48,225) ITL(5),ITL(6),ITL(7)
      CALL FMAX(FRQ,NEF,XFMN,XFMX)
      CALL FMAX(AMP,NEF,YFMN,YFMX)
      WRITE(48,200) NEF,XFMN,XFMX,YFMN,`.FMX
      WRITE(48,210) (FRQ(IO),IO=1,NEF)
      WRITE(48,210) (AMP(IP),IP=1,NEF)
  175 TOTT=DTBN*NBPTS
C      FREQUENCY INCREMENT
      DFB=1./TOTT
      FQB=0.
      WKB=0.
      NBF=NBPTS/2+1
      DO 349 LK=1,NBF
           FRQ(LK)=0.
           AMP(LK)=0.
           XFFT(LK)=0.
  349 CONTINUE
      CALL FFTRC(PRESS,NBPTS,XFFT,IWKB,WKB)
C      AMPLITUDE SPECTRUM
      DO 500 KK=1,NBF
           FQB=FQB+DFB
           FRQ(KK)=FQB
           XRB=REAL(XFFT(KK))/NBPTS
           XIB=AIMAG(XFFT(KK))/NBPTS
           AMP(KK)=SQRT(XRB*XRB+XIB*XIB)*TOTT
  500 CONTINUE
C
      WRITE(48,450) NBF
      IF(IOPT.NE.3) GO TO 165
      ITL(3)=10HBRODE FOUR
      ITL(4)=10HIER AMPLIT
      ITL(5)=10HUDE SPECTR
      ITL(6)=10HUM
      WRITE(48,235) ITL(3),ITL(4),ITL(5),ITL(6)
  235 FORMAT(4A10)
      CALL FMAX(FRQ,NBF,XFMN,XFMX)
      CALL FMAX(AMP,NBF,YFMN,YFMX)
      WRITE(48,840) XFMN,XFMX,YFMN,YFMX
  165 WRITE(48,210) (FRQ(IU),IU=1,NBF)
      WRITE(48,210) (AMP(IE),IE=1,NBF)
      RETURN
      END
      SUBROUTINE FLOOP(TTIM,PRESS,DT,NP,PFILT)
C      ********************************************
C      THIS SUBROUTINE PERFORMS THE LOOPING REQUIRED
C      TO FILTER THE DATA OR THE BRODE UP TO SEVEN
C      TIMES. FOR LESS THAN SEVEN FILTER LEVELS,
```

```
C       FLO MUST BE SET TO 0. IN THE INPUT DECK IN
C       ORDER TO ESCAPE THE LOOP.
C       *********************************************
C
C
      COMMON /FILT/ IFILT,FLO(7),PFDMX(7),PFBMX(7)
      DIMENSION TTIM(1),PRESS(1),PFILT(1)
C
      DO 750 JF=1,7
           IF(FLO(JF).EQ.0.) GO TO 555
           IFLAG=1
           WRITE(48,95) IFLAG
   95      FORMAT(I5)
           WRITE(48,96) FLO(JF)
   96      FORMAT(F10.0)
           DO 725 KF=1,NP
                PFILT(KF)=0.
  725      CONTINUE
C
C       CALL TO FILTER
           CALL FILTER(DT,NP)
           CALL FMAX(PFILT,NP,YFMN,YFMX)
           WRITE(48,100) YFMN,YFMX
  100      FORMAT(2E15.8)
           WRITE(48,105) (TTIM(LF),LF=1,NP)
           WRITE(48,105) (PFILT(MF),MF=1,NP)
  105      FORMAT(10E15.8)
  750 CONTINUE
  555 IFLAG=-1
      WRITE(48,95) IFLAG
      RETURN
      END
      SUBROUTINE SPLINE(TLAST,NP,TTIM,PRESS)
C       *********************************************
C       THIS SUBROUTINE SETS UP A COSINE SQUARED SPLINE
C       FUNCTION AND APPLIES IT TO THE FINAL 15% OF THE
C       PRESSURE HISTORY TO AVOID A FREQUENCY IMPULSE
C       IN TRUNCATED RECORDS.
C       *********************************************
C
      DIMENSION TTIM(1),PRESS(1)
C
      PIE=3.1415927
      K=IFIX(.85*NP)
      N=NP-K+1
      T1=TTIM(K)
      DO 10 J=1,N
           TFACT=(TTIM(K)-T1)/(TLAST-T1)
           SFACT=COS(TFACT*PIE*.5)
           SFACT=SFACT*SFACT
```

```
            PRESS(K)=PRESS(K)*SFACT
            K=K+1
   10 CONTINUE
      RETURN
      END
      SUBROUTINE IMPULSE(IIMP,DT,NP,NI)
C      ****************************************************
C      THIS SUBROUTINE CALCULATES THE IMPULSE OF THE INPUT
C      PRESSURE DATA (IIMP=1) OR OF THE CALCULATED SPEICHER-
C      BRODE (IIMP=2) BY SIMPSON'S APPROXIMATION.
C      ****************************************************
C
C
      COMMON /THIST / TTIM(6000),PRESS(12000),TIMP(2999),PIMP(2999),
     *                PFILT(6000)
C
      NTMP=NP-3
      NI=NTMP/2
      DO 90 I=1,NI
            TIMP(I)=0.
            PIMP(I)=0.
   90 CONTINUE
      IJ=0
      SUMIMP=0.
      DO 80 J=3,NTMP,2
            IJ=IJ+1
            TIMP(IJ)=TTIM(J)
            AREA=(PRESS(J-1)+4.*PRESS(J)+PRESS(J+1))*DT/3.
            SUMIMP=SUMIMP+AREA
            PIMP(IJ)=SUMIMP
   80 CONTINUE
      RETURN
      END
      SUBROUTINE FILTER(DT,NP)
C      ************************************************
C      THIS SUBROUTINE FILTERS THE INPUT PRESSURE HISTORY
C      (DATA OR SPEICHER-BRODE). IT USES THE DIFFERENCE
C      EQUATIONS DERIVED FOR A SECOND ORDER BUTTERWORTH
C      FILTER AS PRESENTED BY STEARNS, 1975.
C      ************************************************
C
C
      COMMON /THIST / TTIM(6000),PRESS(12000),TIMP(2999),PIMP(2999),
     *                PFILT(6000)
      COMMON /COUNT / ICOUNT,IOPT,LFILT
      COMMON /FILT  / IFILT,FLO(7),PFDMX(7),PFBMX(7)
      DATA LFILT/0/
      PI=3.1415927
      S2=SQRT(2.)
      LFILT=LFILT+1
```

```
C
C       LOW PASS FILTER COEFFICIENTS
C
      AT=TAN(PI*FLO(LFILT)*DT)
      AT2=AT*AT
      A1=1.+S2*AT+AT2
      A=AT2/A1
      B1=2.*(AT2-1.)
      B=B1/A1
      C1=1.-S2*AT+AT2
      C=C1/A1
      FAC=1.
C
C       CALCULATE THE FILTERED HISTORY
C
  150 PFILT(1)=A*PRESS(1)
      PFILT(2)=A*(PRESS(2)+2*FAC*PRESS(1))-B*PFILT(1)
      DO 200 I=3,NP
           PC=A*(PRESS(I)+2.*FAC*PRESS(I-1)+PRESS(I-2))
           PFILT(I)=PC-B*PFILT(I-1)-C*PFILT(I-2)
  200 CONTINUE
      RETURN
      END
      SUBROUTINE FMAX(ARY,NA,XMN,XMX)
C      **********************************************
C      THIS SUBROUTINE FINDS THE MAXIMUMS AND MINIMUMS
C      OF THE VARIOUS ARRAYS TO BE PLOTTED BY FOURPLT
C      **********************************************
C
C
      DIMENSION ARY(NA)
C
      XMN = ARY(1)
      XMX = ARY(1)
      IF(NA.EQ.1) RETURN
      DO 10 I=2,NA
        IF(XMN.GT.ARY(I)) XMN = ARY(I)
        IF(XMX.LT.ARY(I)) XMX = ARY(I)
   10   CONTINUE
C
      RETURN
      END
```

APPENDIX B

PROGRAM FREQRES USER'S MANUAL

B.1 INPUT VARIABLES

Table 2 lists all variables used in the input file for program FREQRES and the format in which they occur. In order to run FREQRES, first one has to select two digitized time history records with the same time step and record duration. One of the records should be a loading waveform and is considered the input. The other record should be some type of response time history and is considered the output. From Table 2, NEPTS is the number of discrete data points in each of the digitized records. NSKIP is the skip factor if the user wishes to work with less than NEPTS points. The total number of points from the input and output data records now considered for analysis is

NPT=NEPTS/NSKIP

The digitized time step is multiplied by NSKIP to get a new resultant time step. The discrete data points are averaged locally, so that all NEPTS points read from tape are considered in the analysis. TFAC, XFAC, and AFAC are the time, input data, and output data conversion factors, if the user does not want to work in units as specified on the data record tapes. Also, a -1.0 for XFAC or AFAC will invert the input or output data records, respectively.

ISPBX is a trigger indicating whether or not the user wants to spline the beginning portion of the input time history with a cosine squared spline, such that the input value at zero time is forced to zero. If one

elects to apply this spline, then TSPBX is the time before which the spline is applied to the input data. ISPEX is a trigger indicating whether or not the user wants to apply the cosine squared spline to the final portion of the input time history such that the final input value is forced to zero. TSPEX specifies the time at which the final portion spline begins. If a final portion spline is requested and TSPEX is left blank, then the default is the final 15 percent of the input record duration is splined. ISPBA, TSPBA, ISPEA, and TSPEA describe the spline conditions for the output data record.

From card 3 of Table 2, IBLX is the baseline correction trigger for the input data. Either a constant or a linear baseline correction can be applied. DELPX specifies the amount of baseline correction. SBX is the start time for the baseline correction and EBX is the end time. If SBX and EBX are specified as equal, then the full value of DELPX is added to all input values after time SBX. If EBX is greater than SBX, then the input plot is rotated about the point defined at SBX by the amount DELPX at time EBX. The resulting input data trace can then be used as is or integrated according to the integration trigger INTX. IBLA, DELPA, SBA, EBA, and INTA describe the baseline correction and integration conditions for the output data.

Cards 5 through 16 in Table 2 specify labels for the X and Y axis for all of the different types of plots resulting from a FREQRES run. Table 2 describes the uses of each label. All of the labels should be centered within the first 30 columns of each line of the input file so that the labels are centered on the axis of the plots.

B.2 PROGRAM STRUCTURE

A listing of program FREQRES is provided in Appendix C. Figure 33 provides a flow chart of the program structure. It is easy to follow the program listing as one preceeds through the flow chart, since the program is well documented with comment cards. The first part of the program has extensive comment cards describing the program input file. The first executable part of the program reads the entire input file and then documents all input file conditions in the printed output file. The program then writes the input file conditions to the time history plot file. The input data record time history is read from TAPE26 and then can be baseline corrected, integrated, and/or splined according to input file specifications. The resulting input data record time history is then stored on a plot file (TAPE48) for post-process plotting. The output data record time history is read from TAPE27 and it can also be baseline corrected, integrated, and/or splined according to input file specification. The resulting output data record time history is then stored on the plot file. Another input data record of arbitarary specification (such as a "best-fit" Speicher-Brode waveform to a HEST pressure input data record) is read from TAPE3. If the time step from the new input data record is not within a 1 percent tolerance level of the time step for the input and output data records read earlier, then the program will stop. The time steps should be nearly identical for best results in this analysis procedure. As an example, assume that the time step for input and output data records is 5×10^{-6} seconds and the time step for the new input data record is 1.337×10^{-4} seconds. Then one would have to specify an NSKIP value of $(1.337 \times 10^{-4})/(5 \times 10^{-6}) = 27$

in order to allow the program to run. The resulting time steps would be 1.35×10^{-4} seconds and 1.337×10^{-4} seconds, which are within the 1 percent tolerance level. If the 1 percent tolerance level is too restrictive for some data record combinations, the user may have to relax the tolerance level to 2 percent, or at the most 3 percent, by updating the program.

The program FFT's the input and output data record time histories (see Section 2.2) and stores the FFT amplitude spectrums in the plot file. The FRF is calculated by dividing the output record FFT by the input record FFT (see Section 2.4). The FRF phase angle information is of little interest in this analysis, but FRF amplitude ratios are. Therefore, the FRF amplitude ratios are saved in the plot file.

As was discussed in Section 2.3, the inverse FFT of an FFT does not give back the same exact discrete time series. An inverse FFT is applied directly to the output record FFT, in order to get an output record time history which includes these alterations.

The program then FFT's the new input data record read earlier from TAPE3. This FFT is then multiplied by the FRF through complex math to obtain a new modified output response FFT. The program then inverse FFT's this new FFT to obtain a modified output response time history.

B-3 SAMPLE OUTPUT

Table 3 presents a sample output listing (TAPE6) from a FREQRES calculation. Record number 4 (Figure 6) was the input data record and record number 5 (Figure 7) was the output data record. The output echoes the input file variable specification. This output listing shows that the input and output data records consisted of 9970 points each, but a skip

factor of 27 was used. The large skip factor was used in order to force the time step of the test data records to be equal to the time step of the Speicher-Brode waveform created from a FOURFIT calculation. The Speicher-Brode waveform time step (stated three fourths of the way through the output listing) is 1.337×10^{-4} seconds and the original test data record time step is 5×10^{-6} seconds. The skip factor of 27 now gives the test data records a time step of $(27)(5 \times 10^{-6}$ seconds$) =$ 1.35×10^{-4} seconds, which is within the 1 percent tolerance level used in the program. Next the listing states that the time, input data, and output data conversion factors were all set to 1.0. The beginning portions of the input and output data prior to 2.67 msec and 3.0 msec, respectively, were splined to zero. The final 15 percent of the input and output data were also splined to zero. The "very important notice" in the output listing compares the total number of points and time steps between the Speicher-Brode waveform and the test data. If the total number of points is not identical, then the program truncates the time history with the greatest number of points (the Speicher-Brode waveform in this example) so that they are equal. The program then prints out the time steps for user inspection. If the time steps do not meet the tolerance level specified in FREQRES, the program stops and the final three lines shown in the output listing will not be printed. If the tolerance level is met, then the program should run successfully to completion. The last three lines provide the value of the full integration of the output data record, the value of the output FFT amplitude spectrum at zero frequency, and the value of the offset of the inverse FFT output time history (see Section 2.3). Notice that the first and second values are nearly

identical, and the value of the third is twenty times the value of the second.

Table 4 presents the input file variable specifications for each of the test data records as used in this analysis. Only two of the data records were ever used as input data records in the cause-effect analysis, record numbers 2 and 4. All of the data records with an NSKIP of 35 were used as output data records when record number 2 was used as the input data record. All of the data records with an NSKIP of 27 were associated with record number 4. The time scale was always kept at seconds with TFAC = 1.0. Test data records 8 through 11 were converted from units of g's to ft/sec^2 with an AFAC = 32.2 and then integrated so that the output data record could be velocity rather than acceleration versus time. All of the strain plots were inverted with a AFAC = -1.0 to be consistent with the pressure plots in which compression is positive. Test data record numbers 8 and 11 were the only records which appeared to need baseline correcting as noted in Table 4.

Table 5 presents the total impulse, first FFT value, and inverse FFT offset for test data records 4 through 20.

B.4 PROGRAM FREPLT

Program FREPLT is the post process plotting program for the program FREQRES. A complete listing of FREPLT is presented in Appendix D. FREPLT simply reads the plot file created from a FREQRES run (TAPE48) and creates eight hard copy plots on the DNA Cyber computer at Los Alamos, New Mexico. The eight plots are as follows:

1. Input data record time history
2. Output data record time history
3. Input data record FFT amplitude spectrum up to 3000 Hz

4. Output data record FFT amplitude spectrum up to 3000 Hz
5. FRF amplitude ratios up to 3000 Hz
6. Inverse FFT output record time history
7. Output record FFT with new input data record influence
8. Modified output response time history

B.5 PROGRAMMING NOTES

This subsection mainly discusses file manipulation among the three programs FOURFIT, FREQRES, and FREPLT. First, a FOURFIT calculation is run with the updates discussed in Section 2.5 and shown in Appendix A. These updates create TAPE49 which must be saved.

The input files necessary for a FREQRES calculation are shown in Table 6. The output files created from a successful FREQRES calculation are shown in Table 7. FREPLT only requires one input file, TAPE9, which is the plot file from the FREQRES calculation, TAPE48. FREPLT creates two output files, TAPE6 and PLOT. TAPE6 is printed output. PLOT contains the eight plots described in Secton B 4 which can be disposed to hard copies with a job control instruction:

PESP.ORIENT=ROTATE MAJOR="any message"

From Table 6, TAPE26 and TAPE27 contain digitized test data records as they are stored on EU tapes under a format used by the Waterways Experiment Station in Vicksburg, Mississippi. The format is readily apparent in the listing of FREQRES in Appendix C with the READ statements for TAPE26 and TAPE27.

For all FFT's and FRF's, the maximum frequency of concern for plotting is assumed to be 3000 Hz. There is very little significance at frequencies greater than 3000 Hz in most structural and soil response characteristics. Also, the power in most FFT amplitude spectrums of test data is negligible at 3000 Hz and beyond. This maximum frequency of

concern (for plotting purposes only) can be altered in the portion of FREQRES as stated below:

```
C  Assumming record duration is .05 sec and maximum frequency
C  of concern is 3000 Hz then the maximum number of points of concern
C  for plotting in the frequency domain is (3000)(.05) = 150.
    NPFF = NPF
    IF(NPF.GT.150) NPFF=150
```

If the input and output data record durations are different from .05 seconds or if the maximum frequency of concern for plotting is different from 3000 Hz, then the 150 in the last statement above must be altered accordingly.

APPENDIX C

LISTING OF PROGRAM FREQRES

```
      PROGRAM FREQRES(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     *       TAPE2,TAPE3,TAPE26,TAPE27,TAPE48)
C
C***********************************************************************
C
C     PROGRAM FREQRES DETERMINES THE FREQUENCY RESPONSE FUNTION
C     BETWEEN TWO SETS OF DATA ("INPUT" DATA TRACE X(NT)
C     FROM TAPE26 AND "OUTPUT" DATA TRACE A(NT) FROM
C     TAPE27).  THE "INPUT"/"OUTPUT" LABELS ARE ONLY
C     RELEVANT IN "CAUSE-EFFECT" ANALYSIS BETWEEN TWO SETS
C     OF DATA.
C     RESULTS ARE WRITTEN TO A
C     FILE (TAPE48) TO BE READ AND PLOTTED BY PROGRAM
C     FREPLT.
C
C***********************************************************************
C
      DIMENSION FRQ(3000),XFFT(3000),AFFT(3000),AMP(3000),
     *TIMX(6000),XTD(6000),ATD(6000),DDT(12000),PRESS(6000)
      DIMENSION IX(8),IA(8),ITX(6,4),ITY(6,4)
      DIMENSION DUM(3),IWKE(5500),WKE(5500)
      EQUIVALENCE (IWKE(1),WKE(1))
      DIMENSION COPS(3000),CIPS(3000)
      COMPLEX XFFT,AFFT
C
C***********************************************************************
C***********************************************************************
C
C           TAPE2 INPUT FILE DESCRIPTION
C
C CARD  COLUMN   FORMAT  VARIABLE  DESCRIPTION
C
C  1     1-5      I5      NEPTS    NO. OF POINTS TO BE READ FROM TAPE
C        6-10     I5      NSKIP    SKIP INTERVAL (DEFAULT=1, ALL POINTS
C                                  FROM TAPE ARE SAVED)
C       11-20     E10.3   TFAC     TIME CONVERSION FACTOR (DEFAULT=1.0)
C       21-30     E10.3   XFAC     INPUT DATA CONV. FACTOR (DEFAULT=1.0)
C       31-40     E10.3   AFAC     OUTPUT DATA CONV. FACTOR (DEFAULT=1.0)
C
```

```
C  2     1-5     I5      ISPBX    0: NO SPLINE PERFORMED ON BEGINNING
C                                    OF INPUT DATA
C                                 1: BEGINNING OF INPUT DATA WILL BE
C                                    SPLINED (DEFAULT=0)
C        6-15    E10.3   TSPBX    IF ISPBX=1, A SPLINE IS PERFORMED AT
C                                 THIS TIME BACK TO TIME ZERO (DEFAULT
C                                 IS 0.0 WHICH MEANS NO SPLINE IS DONE)
C       16-20    I5      ISPEX    0: NO SPLINE PERFORMED ON END OF
C                                    INPUT DATA
C                                 1: END OF INPUT DATA WILL BE SPLINED
C                                    (DEFAULT=0)
C       21-30    E10.3   TSPEX    IF ISPEX=1, TIME AT WHICH SPLINE
C                                 BEGINS FOR INPUT DATA (DEFAULT IS
C                                 85% OF TTOT)
C       31-35    I5      ISPBA    0: NO SPLINE PERFORMED ON BEGINNING
C                                    OF OUTPUT DATA
C                                 1: BEGINNING OF OUTPUT DATA WILL BE
C                                    SPLINED (DEFAULT=0)
C       36-45    E10.3   TSPBA    IF ISPBA=1, A SPLINE IS PERFORMED AT
C                                 THIS TIME BACK TO TIME ZERO (DEFAULT
C                                 IS 0.0 WHICH MEANS NO SPLINE IS DONE)
C       46-50    I5      ISPEA    0: NO SPLINE PERFORMED ON END OF
C                                    OUTPUT DATA
C                                 1: END OF OUTPUT DATA WILL BE
C                                    SPLINED (DEFAULT=0)
C       51-60    E10.3   TSPEA    IF ISPEA=1, TIME AT WHICH SPLINE
C                                 BEGINS FOR OUTPUT DATA (DEFAULT
C                                 IS 85% OF TTOT)
C
C  3     1-5     I5      IBLX     INPUT DATA BASELINE CORRECTION TRIGGER
C                                 0: NO BASELINE CORRECTION
C                                 1: BASELINE CORRECTION WITH THE
C                                    FOLLOWING PARAMETERS (DEFAULT=0)
C        6-15    E10.3   DELPX    CORRECTION ADDED TO INPUT DATA VALUES
C                                 AFTER TIME SBX. IF EBX AND SBX ARE
C                                 EQUAL THEN THE FULL VALUE OF DELPX IS
C                                 ADDED AT ALL TIMES AFTER SBX. IF EBX
C                                 IS GREATER THAN SBX THEN THE PLOT IS
C                                 ROTATED ABOUT THE POINT DEFINED AT SBX
C                                 BY THE AMOUNT DELPX AT TIME EBX.
C       16-25    E10.3   SBX      START TIME FOR BASELINE CORRECTION
C                                 (PLOT ROTATION POINT IF EBX > SBX)
C       26-35    E10.3   EBX      END TIME FOR BASELINE CORRECTION
C       36-40    I5      INTX     INPUT DATA INTEGRATION TRIGGER
C                                 0: NO INTEGRATION
C                                 1: INTEGRATE INPUT DATA
C
C  4     1-5     I5      IBLA     OUTPUT DATA BASELINE CORRECTION TRIGGER
C                                 0: NO BASELINE CORRECTION
C                                 1: BASELINE CORRECTION WITH THE
```

```
C                                        FOLLOWING PARAMETERS (DEFAULT=0)
C         6-15     E10.3  DELPA     CORRECTION ADDED TO OUTPUT DATA VALUES
C                                   AFTER TIME SBA. IF EBA AND SBA ARE
C                                   EQUAL THEN THE FULL VALUE OF DELPA IS
C                                   ADDED AT ALL TIMES AFTER SBA. IF EBA
C                                   IS GREATER THAN SBA THEN THE PLOT IS
C                                   ROTATED ABOUT THE POINT DEFINED AT SBA
C                                   BY THE AMOUNT DELPA AT TIME EBA.
C        16-25     E10.3  SBA       START TIME FOR BASELINE CORRECTION
C                                   (PLOT ROTATION POINT IF EBA > SBA)
C        26-35     E10.3  EBA       END TIME FOR BASELINE CORRECTION
C        36-40     I5     INTA      OUTPUT DATA INTEGRATION TRIGGER
C                                   0: NO INTEGRATION
C                                   1: INTEGRATE OUTPUT DATA
C
C NOTE: ALL OF THE FOLLOWING LABELS SHOULD BE CENTERED WITHIN THE
C       FIRST 30 COLUMNS OF EACH LINE OF THE INPUT FILE.
C
C  5      1-40     4A10   ITX       INPUT DATA X-AXIS LABEL; EXAMPLE:
C                                        TIME (SEC)
C
C  6      1-40     4A10   ITY       INPUT DATA Y-AXIS LABEL; EX:
C                                        PRESSURE (PSI)
C
C  7      1-40     4A10   ITX       OUTPUT DATA X-AXIS LABEL; EX:
C                                        TIME (SEC)
C
C  8      1-40     4A10   ITY       OUTPUT DATA Y-AXIS LABEL; EX:
C                                        STRAIN (IN/IN)
C
C  9      1-40     4A10   ITX       INPUT DATA FOURIER AMP. SPEC.
C                                   X-AXIS LABEL; EX:
C                                        FREQUENCY (HZ)
C
C 10      1-40     4A10   ITY       INPUT DATA FOURIER AMP. SPEC.
C                                   Y-AXIS LABEL; EX:
C                                        AMPLITUDE (PSI-SEC)
C
C 11      1-40     4A10   ITX       OUTPUT DATA FOURIER AMP. SPEC.
C                                   X-AXIS LABEL; EX:
C                                        FREQUENCY (HZ)
C
C 12      1-40     4A10   ITY       OUTPUT DATA FOURIER AMP. SPEC.
C                                   Y-AXIS LABEL; EX:
C                                        AMPLITUDE (SEC)
C
C 13      1-40     4A10   ITX       FREQUENCY RESPONSE FUNCTION
C                                   X-AXIS LABEL; EX:
C                                        FREQUENCY (HZ)
C
```

```
C 14      1-40    4A10   ITY      FREQUENCY RESPONSE FUNCTION
C                                 Y-AXIS LABEL; EX:
C                                      FFTA/FFTX
C
C 15      1-40    4A10   ITX      BRODE OUTPUT RESPONSE
C                                 X-AXIS LABEL; EX:
C                                    TIME (SEC)
C
C 16      1-40    4A10   ITY      BRODE OUTPUT RESPONSE
C                                 Y-AXIS LABEL; EX:
C                                     STRAIN (IN/IN)
C
C************************************************************************
C************************************************************************
C
C   IF YOU ENCOUNTER A CM LIMIT ERROR THEN MOST LIKELY THE ARRAY SIZES
C   FOR WKE AND IWKE SPECIFIED ARE TOO SMALL FOR THE VALUE OF NPT
C   PASSED THROUGH THE CALL TO FFTRC OF FFTCC.  THIS ERROR CAN BE
C   AVOIDED BY INCREASING THE SIZE OF THE WKE AND IWKE ARRAYS AND AT
C   THE SAME TIME INCREASING THE CM=? AND RFL,? SPECIFICATIONS IN THE
C   JCL.  NOTE: FOR A 5500 SIZE OF WKE AND IWKE, ?=270000.
C
C***********************************************************************
C
      REWIND2
      REWIND3
      WRITE(6,199)
  199 FORMAT(*    FREQRES OUTPUT LISTING*)
      READ (2,111) NEPTS,NSKIP,TFAC,XFAC,AFAC
  111 FORMAT(2I5,3E10.3)
      SKIP=FLOAT(NSKIP)
      IF (TFAC.EQ.0.) TFAC=1.0
      IF (XFAC.EQ.0.) XFAC=1.0
      IF (AFAC.EQ.0.) AFAC=1.0
      READ (2,115) ISPBX,TSPBX,ISPEX,TSPEX,ISPBA,TSPBA,ISPEA,TSPEA
  115 FORMAT(4(I5,E10.3))
      READ(2,112) IBLX,DELPX,SBX,EBX,INTX
      READ(2,112) IBLA,DELPA,SBA,EBA,INTA
  112 FORMAT(I5,3E10.3,I5)
  113 FORMAT(4A10)
      DO 10 I=1,6
      READ(2,113) (ITX(I,J),J=1,4)
   10 READ(2,113) (ITY(I,J),J=1,4)
   11 CONTINUE
      WRITE(6,127) NEPTS,NSKIP
      WRITE(6,128) TFAC
      WRITE(6,129) XFAC
      WRITE(6,130) AFAC
      IF (ISPBX.EQ.1) WRITE(6,131) TSPBX
      IF (ISPEX.EQ.1.AND.TSPEX.LE.0.0) WRITE(6,132)
```

```
      IF (ISPEX.EQ.1.AND.TSPEX.GT.0.0) WRITE(6,133) TSPEX
      IF (ISPBA.EQ.1) WRITE(6,134) TSPBA
      IF (ISPEA.EQ.1.AND.TSPEA.LE.0.0) WRITE(6,135)
      IF (ISPEA.EQ.1.AND.TSPEA.GT.0.0) WRITE(6,136) TSPEA
      IF (IBLX.EQ.1) WRITE(6,123) DELPX,SBX,EBX
      IF (IBLA.EQ.1) WRITE(6,124) DELPA,SBA,EBA
  123 FORMAT(/,* BASELINE CORRECTION REQUESTED FOR INPUT DATA RECORD*
     +,* WITH:*,/,*  DELPX = *,E10.3,*;  SBX = *,E10.3,*;  EBX = *
     +,E10.3)
  124 FORMAT(/,* BASELINE CORRECTION REQUESTED FOR OUTPUT DATA RECORD*
     +,* WITH:*,/,*  DELPA = *,E10.3,*;  SBA = *,E10.3,*;  EBA = *
     +,E10.3)
  127 FORMAT(/,* THE NUMBER OF POINTS READ FROM THE DATA RECORD TAPES*
     +,* IS *,I5,* WITH A SKIP OF *,I2,* CONSIDERED FOR ANALYSIS*)
  128 FORMAT(/,*    TIME CONVERSION FACTOR      =  *,E10.3)
  129 FORMAT(*    INPUT DATA CONV. FACTOR     =  *,E10.3)
  130 FORMAT(*    OUTPUT DATA CONV. FACTOR    =  *,E10.3)
  131 FORMAT(/,* BEGINNING PORTION OF INPUT DATA SPLINED FROM TIME*
     +,* EQUAL 0.0 TO TIME EQUAL *,E10.3)
  132 FORMAT(/,* FINAL 15% OF INPUT DATA SPLINED TO ZERO*)
  133 FORMAT(/,* INPUT DATA FROM TIME = *,E10.3,* ON SPLINED TO ZERO*)
  134 FORMAT(/,* BEGINNING PORTION OF OUTPUT DATA SPLINED FROM TIME*
     +,* EQUAL 0.0 TO TIME EQUAL *,E10.3)
  135 FORMAT(/,* FINAL 15% OF OUTPUT DATA SPLINED TO ZERO*)
  136 FORMAT(/,* OUTPUT DATA FROM TIME = *,E10.3,* ON SPLINED TO ZERO*)
      WRITE(48,111) NEPTS,NSKIP,TFAC,XFAC,AFAC
      WRITE(48,115) ISPBX,TSPBX,ISPEX,TSPEX,ISPBA,TSPBA,ISPEA,TSPEA
      WRITE(48,112) IBLX,DELPX,SBX,EBX
      WRITE(48,112) IBLA,DELPA,SBA,EBA
      REWIND26
      REWIND27
C
C    READ INPUT DATA RECORD TAPE HEADER INFORMATION
C
      READ(26,30) IX(3),IX(4),
     *            DUM(1),DUM(2),
     *            IX(1),IX(2),
     *            DTD,NP
   30 FORMAT(3(2A10),E15.8,I5)
      IF (EOF(26)) 900,901
  901 NPT=NEPTS/NSKIP
      DTD=TFAC*SKIP*DTD
      TIMX(1)=0.
      DO 12 I=2,NPT
   12 TIMX(I)=TIMX(I-1)+DTD
      TTOT=TIMX(NPT)
      IF (TSPBX LT.0.001*TTOT.OR.TSPBX.GT.TTOT) ISPBX=0
      IF (TSPBA.LT.0.001*TTOT.OR.TSPBA.GT.TTOT) ISPBA=0
C
C    READ INPUT DATA RECORD VALUES
```

```
C
      READ(26,50) (DDT(I),I=1,NEPTS)
   50 FORMAT(5E16.8)
      IF (EOF(26)) 900,902
  902 IM=0
      DO 13 I=NSKIP,NEPTS,NSKIP
      IM=IM+1
      XTD(IM)=0.
      DO 14 J=1,NSKIP
   14 XTD(IM)=XTD(IM)+DDT(I+1-J)
   13 XTD(IM)=(XTD(IM)/SKIP)*XFAC
      IF (IM.LT.NPT) NPT=IM
C
C   BASELINE CORRECTION FOR INPUT DATA
C
      IF (IBLX.EQ.0) GO TO 21
      DO 15 I=1,NPT
   15 IF (SBX.LT.TIMX(I)) GO TO 16
   16 ISBX=I
      IF ((EBX-SBX).GT.(0.001*TTOT)) GO TO 101
      IF (ISBX.GE.NPT) GO TO 990
      GO TO 102
  101 CONTINUE
      DO 17 I=ISBX,NPT
   17 IF (EBX.LT.TIMX(I)) GO TO 18
   18 IEBX=I
      IF (IEBX.LE.ISBX.OR.IEBX.GE.NPT) GO TO 990
      DO 19 I=ISBX,NPT
   19 XTD(I)=XTD(I)+DELPX*((I-ISBX)/(IEBX-ISBX))
      GO TO 21
  102 DO 20 I=ISBX,NPT
   20 XTD(I)=XTD(I)+DELPX
   21 IF (INTX.EQ.1) CALL INTGRT(DTD,NPT,TIMX,XTD,DDT)
      IF (ISPEX.EQ.1) CALL SPLINE(TSBEX,TTOT,NPT,TIMX,XTD)
      IF (ISPBX.EQ.1) CALL BSPLIN(TSPBX,TTOT,NPT,TIMX,XTD)
      IX(5)=10H INPUT DAT
      IX(6)=10HA RECORD:
      IX(7)=10HX(NT)
      IX(8)=10H
      CALL PLTSAV(1,IX,ITX,ITY,NPT,TIMX,XTD)
C
C   READ OUTPUT DATA RECORD TAPE HEADER INFORMATION
C
      READ(27,30) IA(3),IA(4),
     *            DUM(1),DUM(2),
     *            IA(1),IA(2),
     *            DAM,NP
      IF (EOF(27)) 900,903
  903 CONTINUE
C
```

```
C    READ OUTPUT DATA RECORD VALUES
C
      READ(27,50)  (DDT(I),I=1,NEPTS)
      IF (EOF(27)) 900,904
  904 IM=0
      DO 23 I=NSKIP,NEPTS,NSKIP
      IM=IM+1
      ATD(IM)=0.
      DO 24 J=1,NSKIP
   24 ATD(IM)=ATD(IM)+DDT(I+1-J)
   23 ATD(IM)=(ATD(IM)/SKIP)*AFAC
C
C    BASELINE CORRECTION FOR OUTPUT DATA
C
      IF (IBLA.EQ.0) GO TO 31
      DO 25 I=1,NPT
   25 IF (SBA.LT.TIMX(I)) GO TO 26
   26 ISBA=I
      IF ((EBA-SBA).GT.(0.001*TTOT)) GO TO 103
      IF (ISBA.GE.NPT) GO TO 991
      GO TO 104
  103 CONTINUE
      DO 27 I=ISBA,NPT
   27 IF (EBA.LT.TIMX(I)) GO TO 28
   28 IEBA=I
      IF (IEBA.LE.ISBA.OR.IEBA.GE.NPT) GO TO 991
      DO 29 I=ISBA,NPT
   29 ATD(I)=ATD(I)+DELPA*((I-ISBA)/(IEBA-ISBA))
      GO TO 31
  104 DO 39 I=ISBA,NPT
   39 ATD(I)=ATD(I)+DELPA
   31 IF (INTA.EQ.1) CALL INTGRT(DTD,NPT,TIMX,ATD,DDT)
      IF (ISPEA.EQ.1) CALL SPLINE(TSPEA,TTOT,NPT,TIMX,ATD)
      IF (ISPBA.EQ.1) CALL BSPLIN(TSPBA,TTOT,NPT,TIMX,ATD)
      IA(5)=10H OUTPUT DA
      IA(6)=10HTA RECORD:
      IA(7)=10H A(NT)
      IA(8)=10H
      CALL PLTSAV(2,IA,ITX,ITY,NPT,TIMX,ATD)
      SUMIMP=0.
      DO 80 I=2,NPT
      AREA=(ATD(I-1)+ATD(I))*DTD/2.
   80 SUMIMP=SUMIMP+AREA
C
C    READ THE SPEICHER-BRODE FIT TO THE INPUT DATA FROM TAPE3
C
      READ(3,200) NBPTS,DTBP
      READ(3,210) TIM1,((TIMD),IU=2,NBPTS)
      READ(3,210) (PRESS(IP),IP=1,NBPTS)
  200 FORMAT(I5,E15.8)
```

```
  210 FORMAT(10E15.8)
      IF (TIM1.LE.0.) GO TO 251
      NPLUS=TIM1/DTBP
      NBPTS=NBPTS+NPLUS
      NEND=NBPTS-NPLUS
      DO 252 IP=1,NEND
  252 PRESS(NBPTS+1-IP)=PRESS(NBPTS-NPLUS-IP+1)
      DO 253 IP=1,NPLUS
  253 PRESS(IP)=0.
C  CONVERT THE BRODE FIT FROM MPA TO PSI
  251 DO 254 IP=1,NBPTS
  254 PRESS(IP)=PRESS(IP)*145.0377
      WRITE(6,441)
  441 FORMAT(//,1X,80(1H*)//)
      WRITE(6,442) NBPTS,NPT
  442 FORMAT(* VERY IMPORTANT NOTICE:*/
     **    NBPTS FOR THE SPEICHER-BRODE FIT FROM FOURFIT = *,I5/
     **    MUST BE EQUAL TO NPT FROM THIS PROGRAM          = *,I5/
     **    IF NBPTS AND NPT ARE NOT EQUAL, THIS PROGRAM WILL */
     **    TRUNCATE ONE OF THEM TO MAKE THEM EQUAL.*/)
      WRITE(6,443) DTBP,DTD
  443 FORMAT(*   DTBP FOR THE SPEICHER-BRODE FIT FROM FOURFIT =*,E15.8/
     *        *   MUST BE VERY CLOSE TO DTD FROM THIS PROGRAM  =*,E15.8/
     **    IF THEY ARE NOT CLOSE, THIS PROGRAM WILL STOP.*/)
      WRITE(6,441)
      IF (NPT.GT.NBPTS) NPT=NBPTS
      IF (DTBP.LT.0.99*DTD.OR.DTBP.GT.1.01*DTD) STOP
C
C   FOURIER TRANSFORM OF INPUT DATA RECORD
C
      DFE=1./TTOT
      FRQ(1)=0.0
      CALL FFTRC(XTD,NPT,XFFT,IWKE,WKE)
      NPF=NPT/2+1
C
C   ASSUMMING RECORD DURATION IS .05 SEC AND MAXIMUM FREQUENCY
C   OF CONCERN IS 3000 HZ THEN THE MAXIMUM £ OF POINTS OF CONCERN
C   FOR PLOTTING IN THE FREQUENCY DOMAIN IS (3000)(.05) = 150.
C
      NPFF=NPF
      IF (NPF.GT.150) NPFF=150
      XRE=REAL(XFFT(1))/NPT
      XIE=AIMAG(XFFT(1))/NPT
      AMP(1)=SQRT(XRE**2+XIE**2)*TTOT
      DO 32 JK=2,NPF
      FRQ(JK)=FRQ(JK-1)+DFE
      XRE=REAL(XFFT(JK))/NPT
      XIE=AIMAG(XFFT(JK))/NPT
   32 AMP(JK)=SQRT(XRE**2+XIE**2)*TTOT
      IX(5)=10H FOURIER A
```

```
      IX(6)=10HMPLITUDE S
      IX(7)=10HPECTRUM: X
      IX(8)=10H(N/TTOT)
      CALL PLTSAV(3,IX,ITX,ITY,NPFF,FRQ,AMP)
C
C   FOURIER TRANSFORM OF OUTPUT DATA RECORD
C
      CALL FFTRC(ATD,NPT,AFFT,IWKE,WKE)
      DO 33 JK=1,NPF
      ARE=REAL(AFFT(JK))/NPT
      AIE=AIMAG(AFFT(JK))/NPT
   33 AMP(JK)=SQRT(ARE**2+AIE**2)*TTOT
      FFT1=AMP(1)
      IA(5)=10H FOURIER A
      IA(6)=10HMPLITUDE S
      IA(7)=10HPECTRUM: A
      IA(8)=10H(N/TTOT)
      CALL PLTSAV(4,IA,ITX,ITY,NPFF,FRQ,AMP)
C
C   CALCULATE THE FREQUENCY RESPONSE FUNCTION (COMPLEX)
C   AND PLOT UP ITS MAGNITUDE (AMPLITUDE RESPONSE RATIO)
C
      DO 34 JK=1,NPF
      XRE=REAL(XFFT(JK))/NPT
      XIE=AIMAG(XFFT(JK))/NPT
      ARE=REAL(AFFT(JK))/NPT
      AIE=AIMAG(AFFT(JK))/NPT
      COPS(JK)=(ARE*XRE+AIE*XIE)/(XRE**2+XIE**2)
C   COPS(JK) IS THE REAL PART OF THE FREQUENCY RESPONSE FUNCTION
      CIPS(JK)=(XRE*AIE-ARE*XIE)/(XRE**2+XIE**2)
C   CIPS(JK) IS THE IMAGINARY PART OF THE FREQUENCY RESPONSE FUNCTION
      AMP(JK)=SQRT(COPS(JK)**2+CIPS(JK)**2)
   34 CONTINUE
      IX(1)=10H
      IX(2)=10H       FRE
      IX(3)=10HQUENCY RES
      IX(4)=10HPONSE FUNC
      IX(5)=10HTION (AMPL
      IX(6)=10HITUDE RATI
      IX(7)=10HOS)
      IX(8)=10H
      CALL PLTSAV(5,IX,ITX,ITY,NPFF,FRQ,AMP)
C
C   INVERSE FFT FOR OUTPUT DATA RECORD
C
      DO 81 I=1,NPF
      AFFT(I)=CONJG(AFFT(I))
   81 CONTINUE
      CALL FFTCC(AFFT,NPF,IWKE,WKE)
      DO 82 I=1,NPF
```

```
      AFFT(I)=CONJG(AFFT(I))/NPF
   82 CONTINUE
      DTD=TIMX(NPT)/(NPF-1)
      DO 83 I=1,NPF
      TIMX(I+1)=TIMX(I)+DTD
      ARE=REAL(AFFT(I))
      AIE=AIMAG(AFFT(I))
   83 ATD(I)=ARE
      OFFSET=ATD(1)
      DO 84 I=1,NPF
   84 ATD(I)=ATD(I)-OFFSET
      IA(5)=10H OUTPUT RE
      IA(6)=10HCORD FROM
      IA(7)=10HINVERSE FF
      IA(8)=10HT
      CALL PLTSAV(2,IA,ITX,ITY,NPF,TIMX,ATD)
      WRITE(6,444) SUMIMP,FFT1,OFFSET
  444 FORMAT(* OUTPUT RECORD TOTAL IMPULSE = *,E15.6/
     *        * FIRST POINT OF OUTPUT FFT    = *,E15.6/
     *        * OUTPUT INVERSE FFT OFFSET    = *,E15.6//)
C
C   FOURIER TRANSFORM OF THE SPEICHER-BRODE FIT
C
      CALL FFTRC(PRESS,NPT,XFFT,IWKE,WKE)
      DO 59 JK=1,NPF
      XRE=REAL(XFFT(JK))/NPT
      XIE=AIMAG(XFFT(JK))/NPT
      COPSD=COPS(JK)*XRE-CIPS(JK)*XIE
      CIPSD=COPS(JK)*XIE+CIPS(JK)*XRE
      COPS(JK)=COPSD*NPT
   59 CIPS(JK)=CIPSD*NPT
C   COPS(JK) IS NOW THE REAL PART OF THE FFT OF THE OUTPUT RESPONSE
C      IF THE SPEICHER-BRODE FIT WOULD HAVE BEEN THE LOADING INPUT
C   CIPS(JK) IS NOW THE IMAGINARY PART OF THE FFT
      DO 40 JK=1,NPF
   40 AFFT(JK)=CMPLX(COPS(JK),CIPS(JK))
      DO 45 JK=1,NPF
      ARE=REAL(AFFT(JK))/NPT
      AIE=AIMAG(AFFT(JK))/NPT
   45 AMP(JK)=SQRT(ARE**2+AIE**2)*TTOT
      IA(5)=10HSP-BRODE F
      IA(6)=10HFT AMPLITU
      IA(7)=10HDE SPECTRU
      IA(8)=10HM
      CALL PLTSAV(4,IA,ITX,ITY,NPFF,FRQ,AMP)
C
C   INVERSE FFT THE SPEICHER-BRODE OUTPUT RESPONSE AFFT(JK)
C
      DO 41 I=1,NPF
      AFFT(I)=CONJG(AFFT(I))
```

```
   41 CONTINUE
      CALL FFTCC(AFFT,NPF,IWKE,WKE)
      DO 42 I=1,NPF
      AFFT(I)=CONJG(AFFT(I))/NPF
   42 CONTINUE
      ARE=REAL(AFFT(I))
      AIE=AIMAG(AFFT(I))
   43 ATD(I)=ARE
      OFFSET=ATD(1)
      DO 44 I=1,NPF
   44 ATD(I)=ATD(I)-OFFSET
      IA(5)=10H OUTPUT RE
      IA(6)=10HCORD IF LO
      IA(7)=10HADING WERE
      IA(8)=10H SP-BRODE
      CALL PLTSAV(6,IA,ITX,ITY,NPF,TIMX,ATD)
      GO TO 999
  900 WRITE(6,70)
   70 FORMAT(1H ,*END-OF-FILE REACHED EARLY*,///)
      GO TO 999
  990 WRITE(6,71)
   71 FORMAT(1H ,*ERROR IN BASELINE CORRECTION INSTRUCTIONS FOR *,
     +*INPUT DATA*,///)
      GO TO 999
  991 WRITE(6,72)
   72 FORMAT(1H ,*ERROR IN BASELINE CORRECTION INSTRUCTIONS FOR *,
     +*OUTPUT DATA*,///)
  999 END
      SUBROUTINE PLTSAV(N,ITLT,IXL,IYL,NN,XP,YP)
      DIMENSION ITLT(1),IXL(6,1),IYL(6,1),XP(1),YP(1)
      WRITE(48,35) (ITLT(L),L=1,8)
   35 FORMAT(8A10)
      WRITE(48,36) (IXL(N,L),L=1,4)
   36 FORMAT(4A10)
      WRITE(48,36) (IYL(N,L),L=1,4)
      CALL FMAX(XP,NN.XPMN.XPMX)
      CALL FMAX(YP,NN,YPMN,YPMX)
      WRITE(48,37) NN,XPMN,XPMX,YPMN,YPMX
   37 FORMAT(I5,4E15.8)
      WRITE(48,38) (XP(K),K=1,NN)
      WRITE(48,38) (YP(K),K=1,NN)
   38 FORMAT(10E15.8)
      RETURN
      END
      SUBROUTINE FMAX(ARY,NA,XMN,XMX)
C   ***************************************************
C   THIS SUBROUTINE FINDS THE MAXIMUMS AND MINIMUMS
C   OF THE VARIOUS ARRAYS TO BE PLOTTED BY FREPLT
C   ***************************************************
      DIMENSION ARY(1)
```

```
C
      XMN = ARY(1)
      XMX = ARY(1)
      IF(NA.EQ.1) RETURN
      DO 10 I=2,NA
      IF(XMN.GT.ARY(I)) XMN = ARY(I)
      IF(XMX.LT.ARY(I)) XMX = ARY(I)
   10 CONTINUE
C
      RETURN
      END
      SUBROUTINE SPLINE(TBGN,TLAST,NP,TTIM,PRESS)
C***********************************************************************
C   THIS SUBROUTINE SETS UP A COSINE SQUARED SPLINE
C   FUNCTION AND APPLIES IT TO THE FINAL PORTION
C   (DEFAULT=15%) OF THE DATA RECORD TO AVOID AN
C   INFINITE IMPULSE AT ZERO FREQUENCY FOR RECORDS
C   WHICH DO NOT RETURN TO ZERO
C***********************************************************************
      DIMENSION TTIM(1),PRESS(1)
C
      PIE=3.1415927
      SPN=TBGN/TLAST
      IF (SPN.LT.0.01) SPN=0.85
      K=IFIX(SPN*NP)
      N=NP-K+1
      T1=TTIM(K)
      DO 10 J=1,N
      TFACT=(TTIM(K)-T1)/(TLAST-T1)
      SFACT=COS(TFACT*PIE*.5)
      SFACT=SFACT**2
      PRESS(K)=PRESS(K)*SFACT
      K=K+1
   10 CONTINUE
      RETURN
      END
      SUBROUTINE BSPLIN(TBGN,TLAST,NP,TTIM,PRESS)
C*********************************************************************
C   THIS SUBROUTINE APPLIES A COSINE SQUARED SPLINE
C   TO THE BEGINNING PORTION OF THE DATA RECORD TO
C   AVOID AN INFINITE IMPULSE AT ZERO FREQUENCY FOR
C   RECORDS WHICH DO NOT START AT ZERO
C*********************************************************************
C
      DIMENSION TTIM(1),PRESS(1)
C
      PIE=3.1415927
      SPN=TBGN/TLAST
      K=IFIX(SPN*NP)
      T1=TTIM(K)
```

```
      DO 10 J=1,K
      TFACT=(T1-TTIM(J))/T1
      SFACT=COS(TFACT*PIE*.5)
      SFACT=SFACT**2
   10 PRESS(J)=PRESS(J)*SFACT
      RETURN
      END
      SUBROUTINE INTGRT(DTD,NP,TTIM,PRESS,DUM)
C*********************************************************
C   THIS SUBROUTINE PERFORMS AN INTEGRATION OF
C   DIGITIZED DATA ACCORDING TO THE TRAPEZOIDAL RULE
C*********************************************************
      DIMENSION TTIM(1),PRESS(1),DUM(1)
      PRESS(1)=0.
      SUMIMP=0.
      DO 80 J=2,NP
      AREA=(PRESS(J-1)+PRESS(J))*DTD/2.
      SUMIMP=SUMIMP+AREA
   80 DUM(J)=SUMIMP
      DO 81 I=2,NP
   81 PRESS(I)=DUM(I)
      RETURN
      END
```

APPENDIX D

LISTING OF PROGRAM FREPLT

```
      PROGRAM FREPLT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     *                   TAPE9,PLOT)
      COMMON /PLOTV/ ITL(8),ISTL(8),IDB
      COMMON /PID/ NPTS,NSKIP,TFAC,XFAC,AFAC,
     *ISPBX,TSPBX,ISPEX,TSPEX,ISPBA,TSPBA,ISPEA,TSPEA,
     *IBLX,DELPX,SBX,EBX,IBLA,DELPA,SBA,EBA
      DIMENSION XARY(9000),YARY(9000),LABX(4),LABY(4)
      CALL GPLOT(1HU,7HARABING,7)
      CALL BGNPL(-1)
      READ(9,111) NPTS,NSKIP,TFAC,XFAC,AFAC
      READ(9,115) ISPBX,TSPBX,ISPEX,TSPEX,ISPBA,TSPBA,ISPEA,TSPEA
      READ(9,112) IBLX,DELPX,SBX,EBX
      READ(9,112) IBLA,DELPA,SBA,EBA
  111 FORMAT (2I5,3E10.3)
  112 FORMAT (I5,3E10.3)
  115 FORMAT (4(I5,E10.3))
      NPLT=8
      DO 10 ID=1,NPLT
      READ(9,120) (ITL(I),I=1,8)
  120 FORMAT(8A10)
  121 FORMAT(4A10)
      READ(9,121) (LABX(I),I=1,4)
      READ(9,121) (LABY(I),I=1,4)
      READ(9,130) NEPTS,XPMN,XPMX,YPMN,YPMX
  130 FORMAT(I5,4E15.8)
      READ(9,140) (XARY(K),K=1,NEPTS)
      READ(9,140) (YARY(L).L=1,NEPTS)
  140 FORMAT(10E15.8)
      IK=1
      IF (ID.LT.6) GO TO 10
      IF (ID.LE.2.OR.ID.EQ.6.OR.ID.EQ.8) GO TO 151
C     NEPTS=150
C     XPMX=2990.
  151 CONTINUE
      CALL PLOTTER(XARY,YARY,NEPTS,XPMN,XPMX,YPMN,YPMX,IK,LABX,LABY)
      CALL ENDPL(-1)
   10 CONTINUE
      CALL GDONE
      END
```

```
      SUBROUTINE PLOTTER(XARY,YARY,NP,XMN,XMX,YMN,YMX,KIND,LABX,LABY)
C
      COMMON /PLOTV/ ITL(8),ISTL(8),IDB
      COMMON /PID/ NPTS,NSKIP,TFAC,XFAC,AFAC,
     *ISPBX,TSPBX,ISPEX,TSPEX,ISPBA,TSPBA,ISPEA,TSPEA,
     *IBLX,DELPX,SBX,EBX,IBLA,DELPA,SBA,EBA
      DIMENSION XARY(NP),YARY(NP),LABX(4),LABY(4)
      WRITE(6,2300) NP,XMN,XMX,YMN,YMX,KIND
 2300 FORMAT(5X,* ENTERED PLOTTER *,/,
     * *NP,XMN,XMX,YMN,YMX,KIND = *,I5,4(1X,E10.4),I5)
      CALL HEIGHT(0.1)
      IF(KIND.LT.0) GO TO 200
C
      IF(KIND.EQ.2) GO TO 100
C
C    ***** IF KIND.EQ.1 THEN PLOT IS LINEAR-LINEAR *****
C
   50 LINET = 0
      LINES = 0
C
      CALL SCL1(XMN,XMX,XORG,XSTP,XEND)
      CALL SCL1(YMN,YMX,YORG,YSTP,YEND)
      WRITE(6,2303) XORG,XSTP,XEND,YORG,YSTP,YEND
 2303 FORMAT(2X,*LINEAR PLOT *,6(2X,E15.6))
      CALL RLINER(XORG,XSTP,XEND,YORG,YSTP,YEND,LABX,LABY)
      CALL DRAWC(XARY,YARY,NP,LINET,LINES)
      GO TO 400
C
C      ***** IF KIND.EQ.2 THEN PLOT IS LOG-LOG *****
C
  100 LINET = 0
      LINES = 0
C
      CALL SCL2(XMN,XMX,XORG,XCYC,KIND)
      IF(KIND.EQ.1) GO TO 50
      CALL SCL2(YMN,YMX,YORG,YCYC,KIND)
      IF(KIND.EQ.1) GO TO 50
      WRITE(6,2305) XORG,XCYC,YORG,YCYC
 2305 FORMAT(5X,*LOG-LOG PLOT     *,4(2X,E15.6))
      CALL LOGLLL(XORG,XCYC,YORG,YCYC,LABX,LABY)
      CALL DRAWC(XARY,YARY,NP,LINET,LINES)
      GO TO 400
C
C     ***** IF KIND.LT.0 THEN PLOT AN OVERLAY *****
C
  200 LINET = LINET+1
      WRITE(6,2307)
 2307 FORMAT(5X,* OVERLAY PLOT *)
      CALL BLOFF(IDB)
      CALL MESSAG(ISTL,80,0.0,6.25)
```

```
      CALL MESSAG(4HDATA,4,4.5,5.8)
      CALL STRTPT(5.2,5.8)
      CALL CONNPT(5.8,5.8)
      CALL MESSAG(4HFIT ,4,4.5,5.6)
      CALL DASH
      CALL STRTPT(5.2,5.6)
      CALL CONNPT(5.8,5.6)
      CALL RESET(4HDASH)
C
      CALL DRAWC(XARY,YARY,NP,LINET,LINES)
  400 CONTINUE
      CALL MESSAG(30HNO. OF PTS READ FROM TAPE    =,30,6.1,5.5)
      CALL INTNO(NPTS,8.8,5.5)
      CALL MESSAG(30HSKIP FACTOR                  =,30,6.1,5.25)
      CALL INTNO(NSKIP,8.8,5.25)
      CALL MESSAG(30HTIME CONVERSION FACTOR       =,30,6.1,5.)
      CALL REALNO(TFAC,2,8.8,5.)
      CALL MESSAG(30HINPUT DATA CONV. FACTOR      =,30,6.1,4.75)
      CALL REALNO(XFAC,2,8.8,4.75)
      CALL MESSAG(30HOUTPUT DATA CONV. FACTOR     =,30,6.1,4.5)
      CALL REALNO(AFAC,2,8.8,4.5)
      TNP=4.5
      IF (ISPBX.NE.1) GO TO 11
      TNP=TNP-.25
      CALL MESSAG(30HBEG. INPUT SPLINE BEFORE      ,30,6.1,TNP)
      CALL REALNO(TSPBX,4,8.8,TNP)
   11 IF (ISPEX.NE.1) GO TO 12
      TNP=TNP-.25
      CALL MESSAG(30HEND INPUT SPLINE AFTER        ,30,6.1,TNP)
      CALL REALNO(TSPEX,4,8.8,TNP)
   12 IF (ISPBA.NE.1) GO TO 13
      TNP=TNP-.25
      CALL MESSAG(30HBEG. OUTPUT SPLINE BEFORE     ,30,6.1,TNP)
      CALL REALNO(TSPBA,4,8.8,TNP)
   13 IF (ISPEA.NE.1) GO TO 14
      TNP=TNP-.25
      CALL MESSAG(30HEND OUTPUT SPLINE AFTER       ,30,6.1,TNP)
      CALL REALNO(TSPEA,4,8.8,TNP)
   14 IF (IBLX.NE.1) GO TO 15
      TNP=TNP-.25
      CALL MESSAG(30HINPUT DATA BASELINE CORRECTION,30,6.1,TNP)
      TNP=TNP-.25
      CALL MESSAG(30H                     DELPX   =,30,6.1,TNP)
      CALL REALNO(DELPX,2,8.8,TNP)
      TNP=TNP-.25
      CALL MESSAG(30H                     SBX     =,30,6.1,TNP)
      CALL REALNO(SBX,4,8.8,TNP)
      TNP=TNP-.25
      CALL MESSAG(30H                     EBX     =,30,6.1,TNP)
      CALL REALNO(EBX,4,8.8,TNP)
```

```
   15 IF (IBLA.NE.1) GO TO 900
      TNP=TNP-.25
      CALL MESSAG(31HOUTPUT DATA BASELINE CORRECTION,31,6.1,TNP)
      TNP=TNP-.25
      CALL MESSAG(30H                        DELPA   = ,30,6.1,TNP)
      CALL REALNO(DELP),2,8.8,TNP)
      TNP=TNP-.25
      CALL MESSAG(30H                        SBA     = ,30,6.1,TNP)
      CALL REALNO(SBA,4,8.8,TNP)
      TNP=TNP-.25
      CALL MESSAG(30H                        EBA     = ,30,6.1,TNP)
      CALL REALNO(EBA,4,8.8,TNP)
  900 CONTINUE
      RETURN
      END
      SUBROUTINE SCL1(XMN,XMX,AORG,ASTP,AMAX)
      DIMENSION S(7)
C
C     ***** FIND LINEAR SCALES *****
C
      WRITE(6,2300) XMN,XMX
 2300 FORMAT(5X,*SUBROUTINE SCL1   XMN,XMX = *,2(E15.6,2X))
      SMIN = 0.00006
      S(1) = 0.00012
      S(2) = 0.00018
      S(3) = 0.00024
      S(4) = 0.00030
      S(5) = 0.00036
      S(6) = 0.00060
      S(7) = 0.00120
C
      DIF = XMX - XMN
      IF(DIF.LT.S(1)) GO TO 90
    5 CONTINUE
      DO 10 I=1,7
        IU = I
   10   IF(DIF.LT.S(I)) GO TO 30
      DO 20 J=1,7
   20   S(J) = S(J)*10.0
      IF(S(1).GT.1.0E15) STOP111
      GO TO 5
C
   30 DMAX = S(IU)
      DSTP = DMAX/6.0
C
C               DETERMINE OFFSET
C
      IF(XMN.LT.0.0) GO TO 60
      DORG = 0.0
      IF(XMN.LT.DSTP) GO TO 99
```

```
      OFFSET = DSTP
   35 OFFSET = OFFSET+DSTP
      IF(XMN.GT.OFFSET) GO TO 35
      DORG = OFFSET-DSTP
      DMAX = DMAX+DORG
      GO TO 99
C
   60 OFFSET = 0.0
   65 OFFSET = OFFSET-DSTP
      IF(XMN.LT.OFFSET) GO TO 65
      DORG = OFFSET
      DMAX = DMAX+DORG
      IF(XMX.LT.DMAX) GO TO 99
      IF(IU.LT.7) DMAX = S(IU+1)
      IF(IU.EQ.7) DMAX = S(2)*10.0
      DSTP = DMAX/6.0
      GO TO 60
C
C                   DIFFERENCE IS ZERO
C
   90 CONTINUE
      DORG = XMN-SMIN
      DMAX = XMN+SMIN
      DSTP = SMIN/3.0
C
   99 AORG = DORG
      ASTP = DSTP
      AMAX = DMAX
      WRITE(6,2303) DORG,DSTP,DMAX
 2303 FORMAT(5X,* LEAVING SCL1    *,3(E15.6,2X))
C
      RETURN
      END
      SUBROUTINE SCL2(XMN,XMX,AORG,ACYC,KIND)
C
C                             SCALE FOR LOG-LOG PLOTS
C
      WRITE(6,2300) XMN,XMX
 2300 FORMAT(5X,*ENTER SCL2       *,2(E15.6,2X))
      IF(XMN.LT.1.0E-8) GO TO 80
      IF(XMX.LT.1.0E-8) GO TO 81
C
      SMN = ALOG10(XMN)
      SMX = ALOG10(XMX)
      MN = IFIX(SMN)
      IF(SMN.LT.0.0) MN=MN-1
      MX = IFIX(SMX)
      AORG = 10.**MN
      DIF = (MX-MN)+1
      IF(MN.LT.0 .AND. MX.LT.0) DIF = MX-MN
```

```
      ACYC = ABS(6.0/DIF)
      GO TO 90
C
   80 WRITE(6,1000) XMN
 1000 FORMAT(5X,*XMN = *,E15.6,*  A LINEAR PLOT WILL BE MADE.*)
      GO TO 82
   81 WRITE(6,1001) XMX
 1001 FORMAT(5X,*XMX = *,E15.6,*  A LINEAR PLOT WILL BE MADE.*)
   82 KIND = 1
C
   90 CONTINUE
      WRITE(6,2303) MN,MX,DIF,AORG,ACYC
 2303 FORMAT(5X,*LEAVING SCL2     MN,MX,DIF,AORG,ACYC*,2I5,3(1X,E15.6))
      RETURN
      END
      SUBROUTINE DRAWC(X,Y,NP,LINET,LINES)
      DIMENSION X(NP),Y(NP)
C
      WRITE(6,2300) NP,LINET,LINES
 2300 FORMAT(5X,*ENTER DRAWC      NP,LINET,LINES = *,3I5)
      IF(LINET.LE.0) GO TO 10
      IF(LINET.EQ.1) CALL DASH
      IF(LINET.EQ.2) CALL CHNDOT
      IF(LINET.EQ.3) CALL CHNDSH
      IF(LINET.EQ.4) CALL DOT
C
   10 CALL CURVE(X,Y,NP,LINES)
C
      IF(LINET.LE.0) GO TO 99
      CALL RESET(3HALL)
      CALL HEIGHT(0.1)
C
   99 CONTINUE
      RETURN
      END
      SUBROUTINE RLINER(XORG,XSTP,XEND,YORG,YSTP,YEND,LABX,LABY)
C     COMMON /COUNT/ ICOUNT,IOPT,LFILT
      COMMON /PLOTV/ ITL(8),ISTL(8),IDB
      DIMENSION LABX(3),LABY(3)
C
      WRITE(6,2300)
 2300 FORMAT(5X,*ENTERED RLINER...............*)
      CALL PAGE(10.5,8.5)
      CALL PHYSOR(1.0,1.0)
      CALL XNAME(LABX,30)
      CALL YNAME(LABY,30)
      CALL AREA2D(6.0,6.0)
C     IF(IOPT.EQ.1) CALL BLREC(4.4,5.5,1.6,0.5,1.0)
C     IF(IOPT.EQ.1) CALL BLKEY(IDB)
      CALL MESSAG(ITL,80,0.0,6.5)
```

```
      CALL GRAF(XORG,XSTP,XEND,YORG,YSTP,YEND)
      CALL DOT
      CALL GRID(1,1)
      CALL RESET(3HDOT)
C
      RETURN
      END
      SUBROUTINE LOGLLL(XOR,XCY,YOR,YCY,LABX,LABY)
C     COMMON /COUNT/ ICOUNT,IOPT,LFILT
      COMMON /PLOTV/ ITL(8),ISTL(8),IDB
      DIMENSION LABX(3),LABY(3)
C
      WRITE(6,2300)
 2300 FORMAT(5X,*ENTERED LOGLLL................*)
      CALL PAGE(10.5,8.5)
      CALL PHYSOR(1.0,1.0)
      CALL XNAME(LABX,30)
      CALL YNAME(LABY,30)
      CALL AREA2D(6.0,6.0)
C     IF(IOPT.EQ.1) CALL BLREC(4.4,5.5,1.6,0.5,1.0)
C     IF(IOPT.EQ.1) CALL BLKEY(IDB)
      CALL MESSAG(ITL,80,0.0,6.5)
      CALL LOGLOG(XOR,XCY,YOR,YCY)
      CALL DOT
      CALL GRID(1,1)
      CALL RESET(3HDOT)
C
      RETURN
      END
```

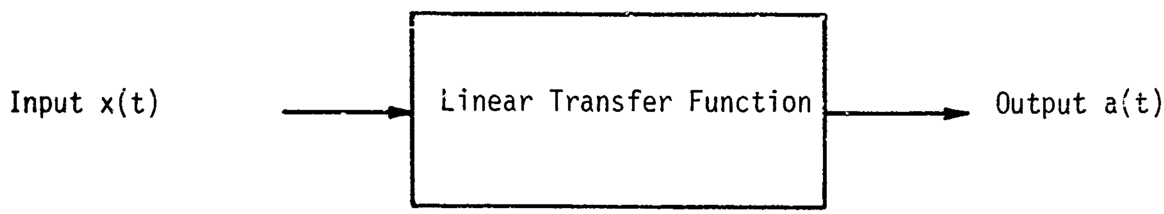


Figure 1. Linear cause-effect relationship between two data records.

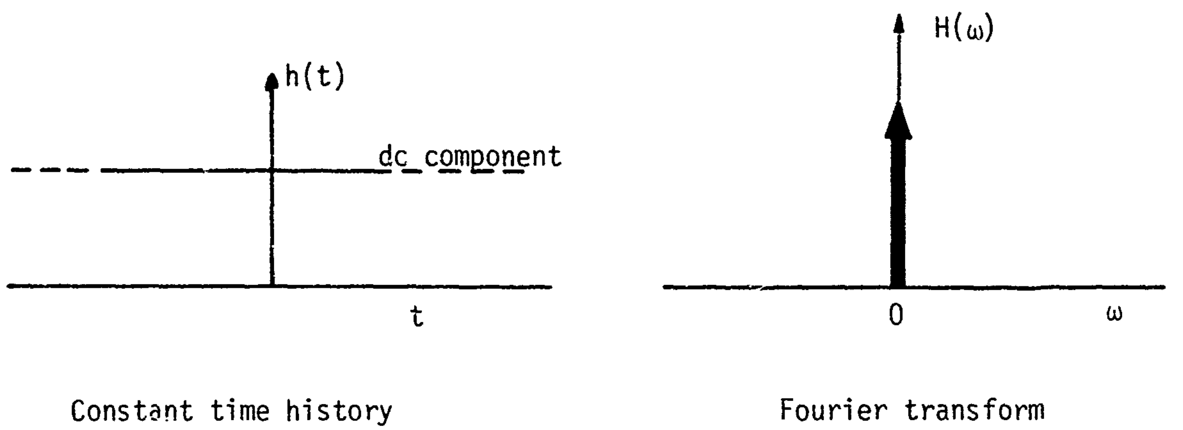
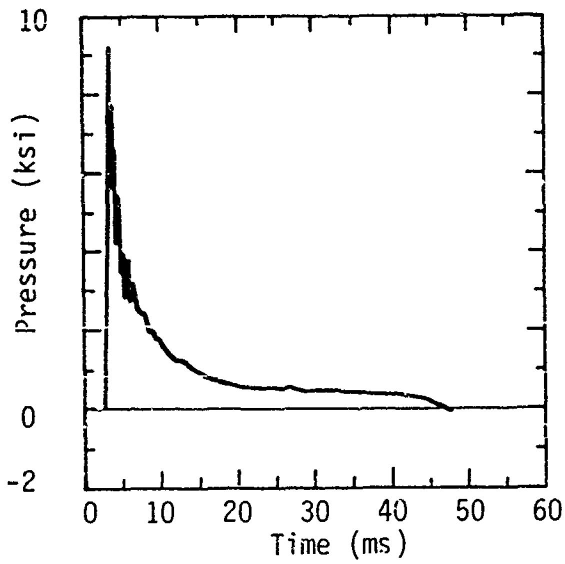
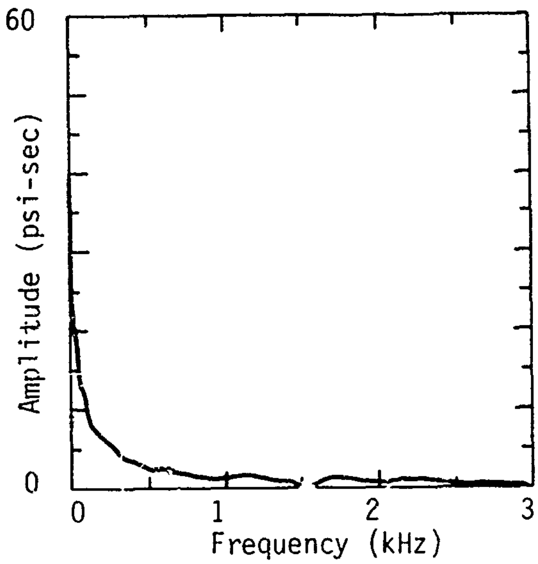


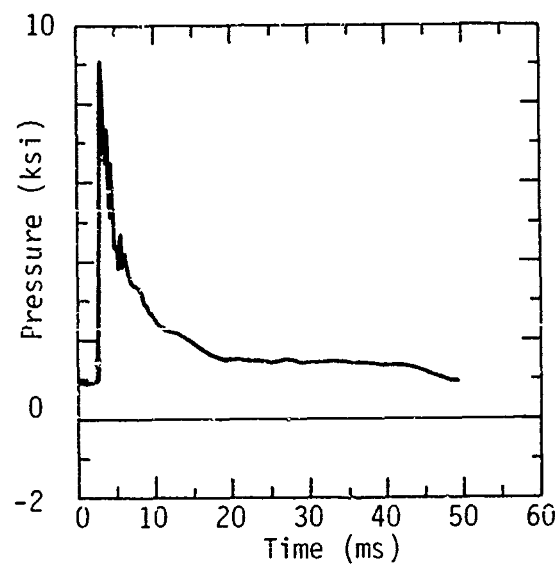
Figure 2. Constant time history and its Fourier transform.



(a) Record #6 time history



(b) Record #6 FFT



(c) Record #6 after direct Inverse FFT

Figure 3. Illustration of an original time history, an FFT, and an Inverse FFT.

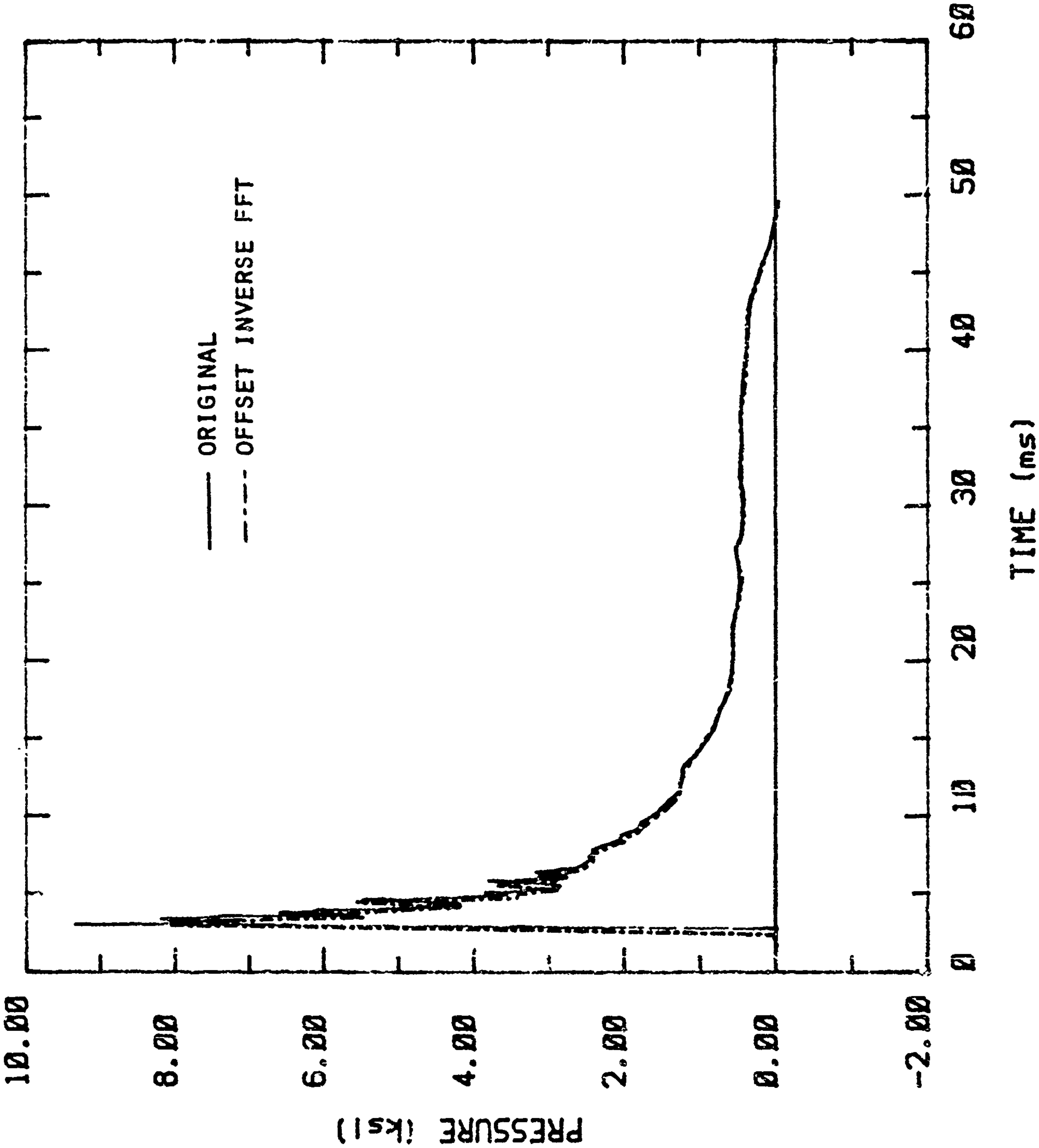


Figure 4. Comparison of the original record #6 and an offset Inverse FFT.

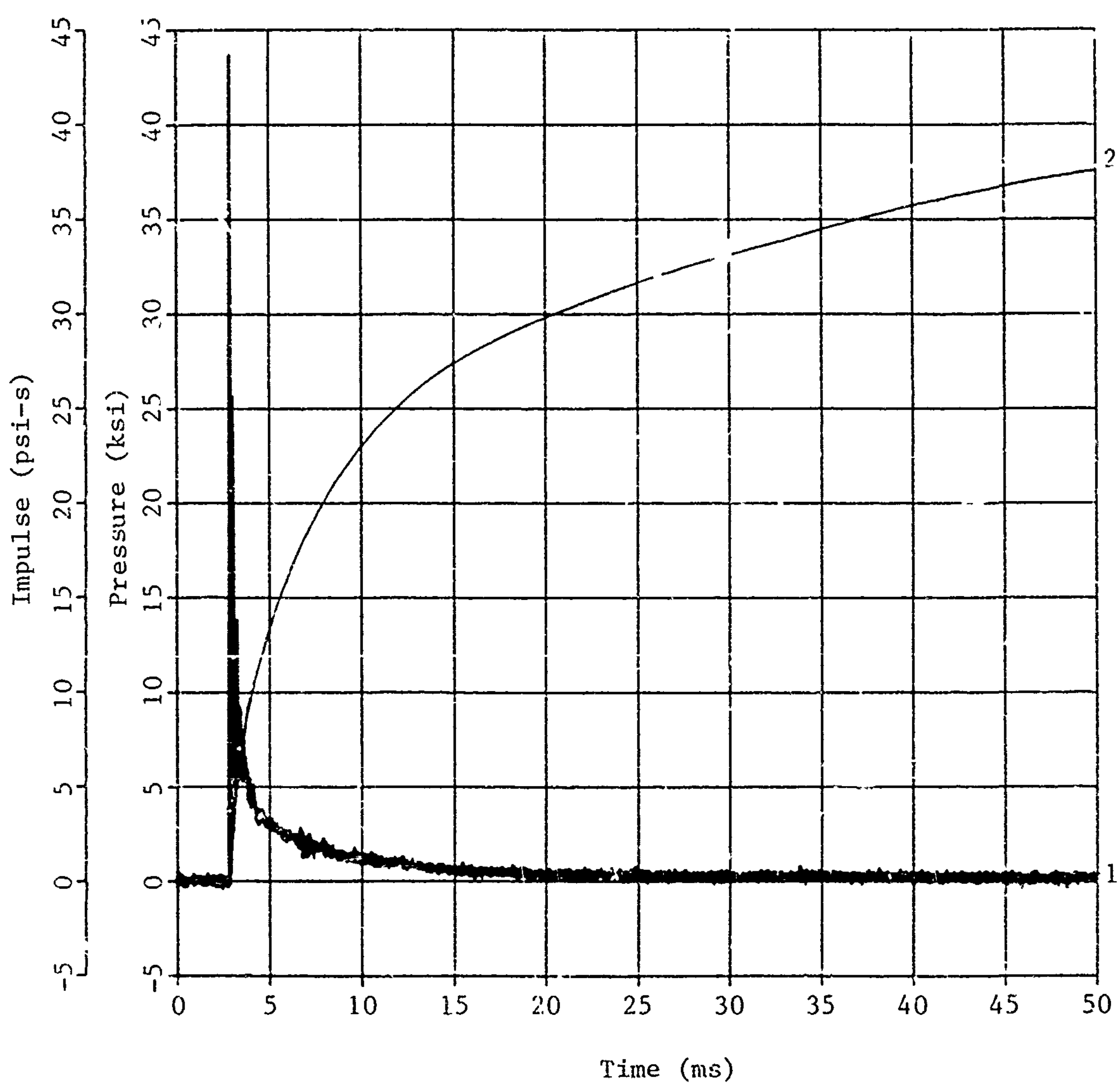


Figure 5. Record #2, HEST pressure on the structure.

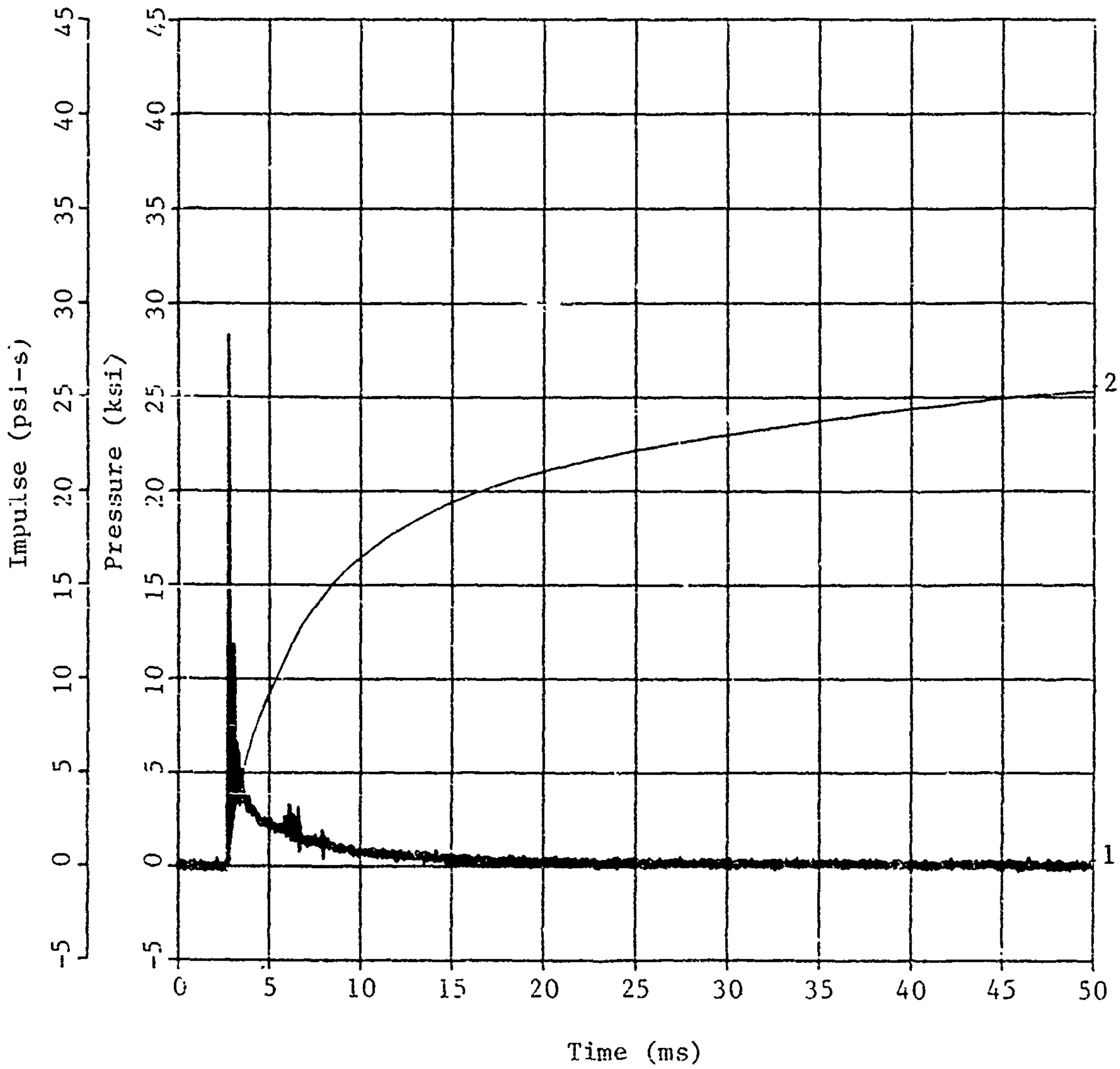


Figure 6. Record #4, HEST pressure on the soil.

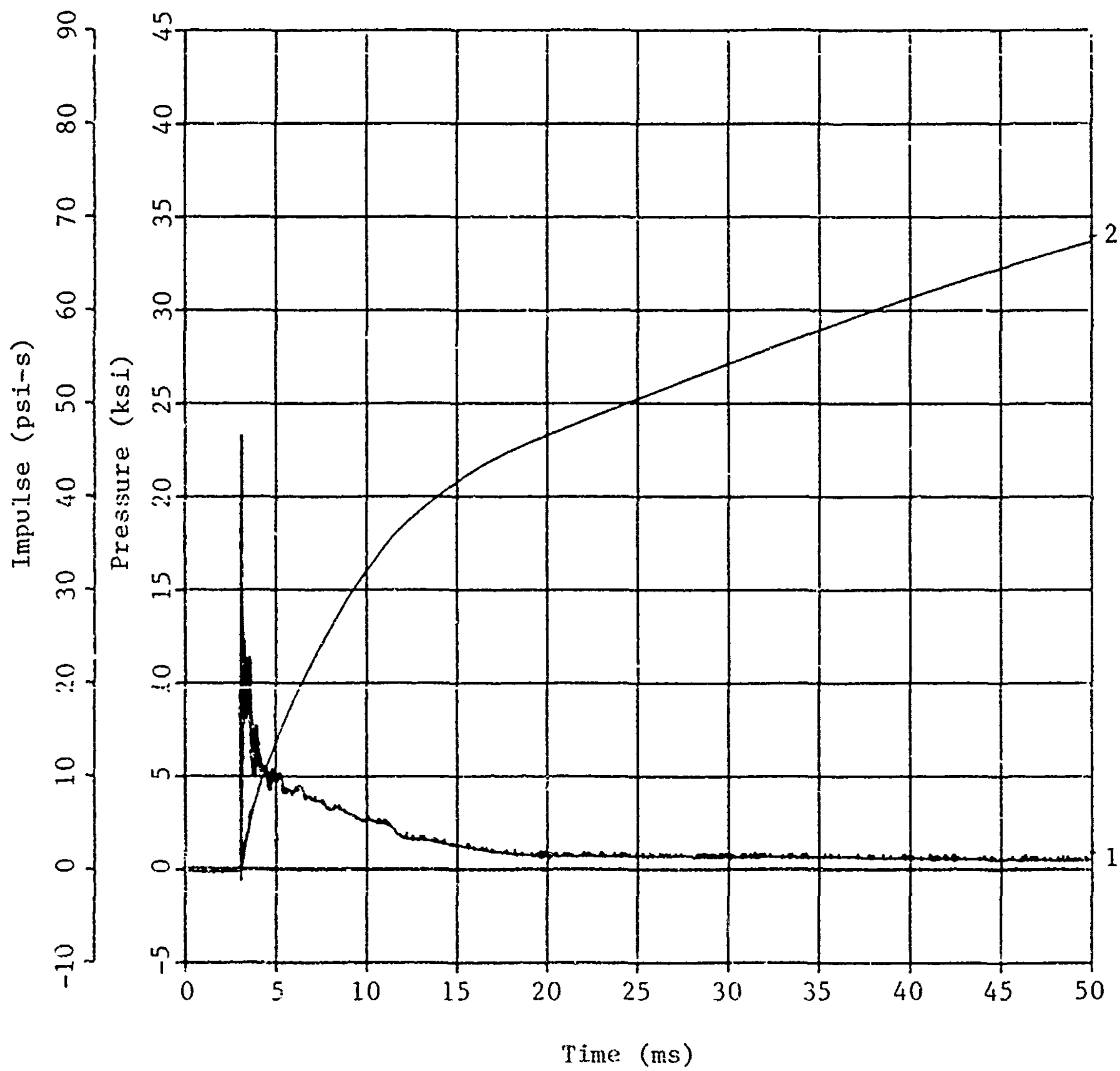


Figure 7. Record #5, soil pressure at 0.6' depth.

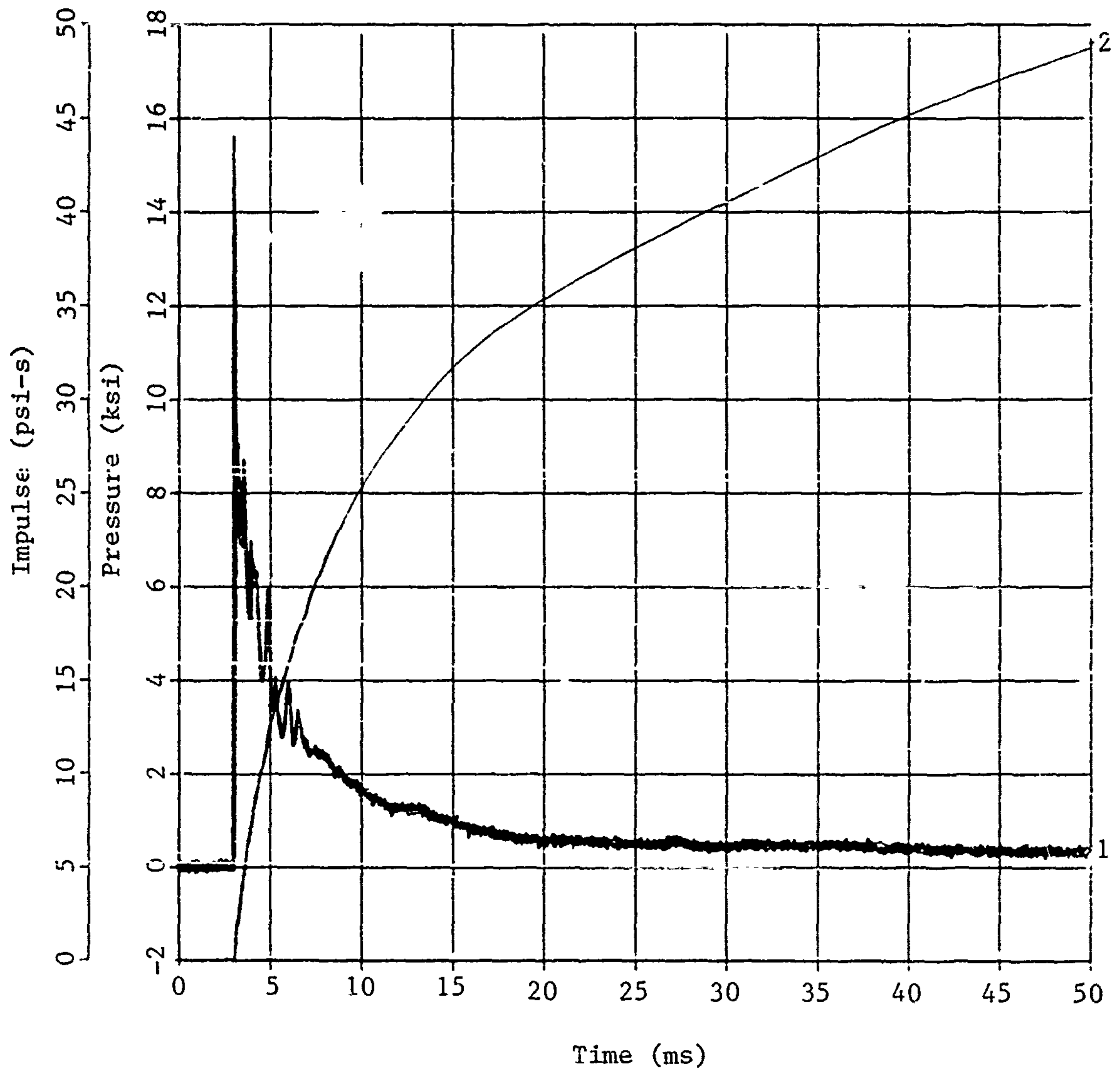


Figure 8. Record #6, soil pressure at 0.5' depth.

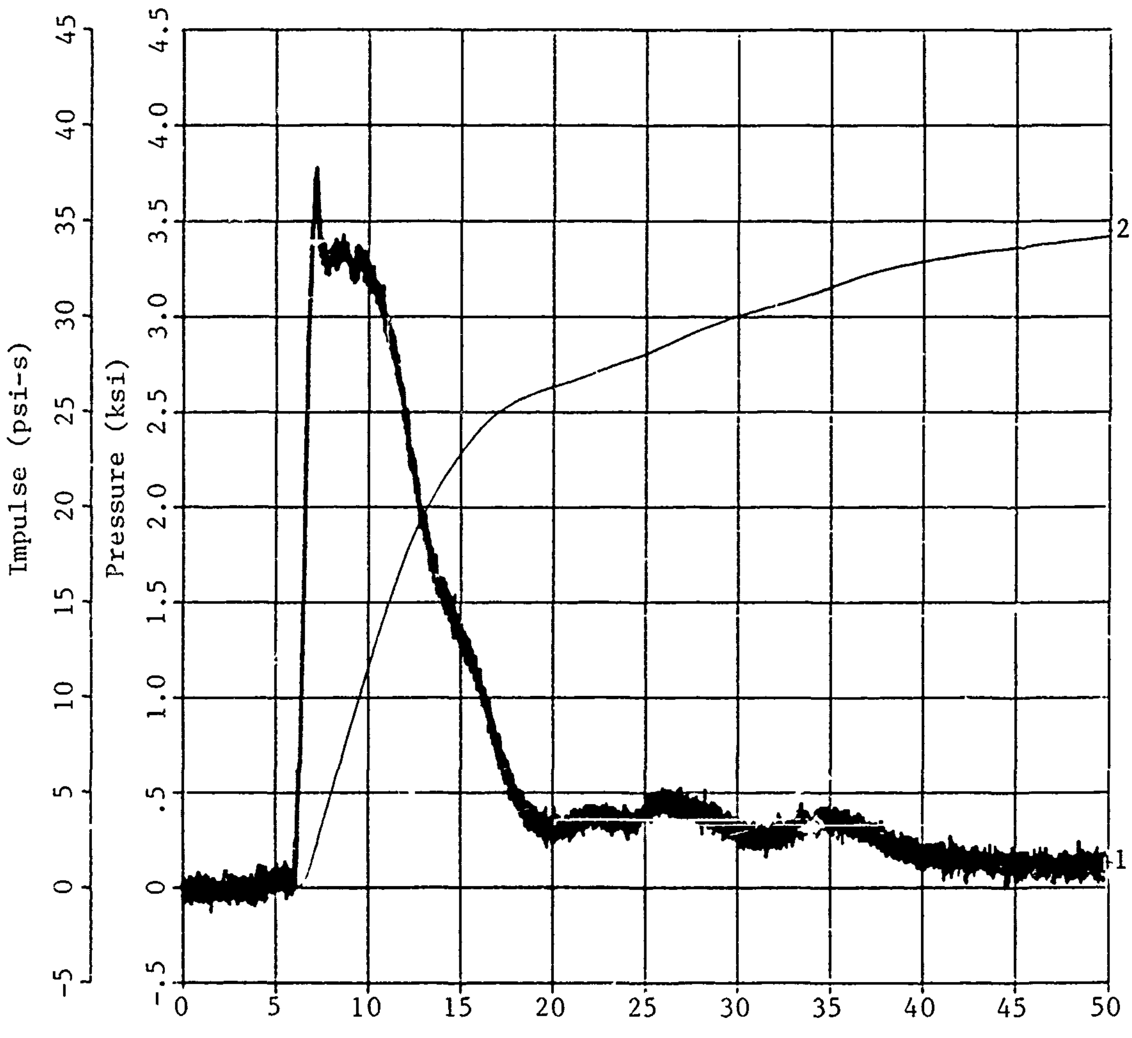


Figure 9. Record #7, soil pressure at 5.21' depth.

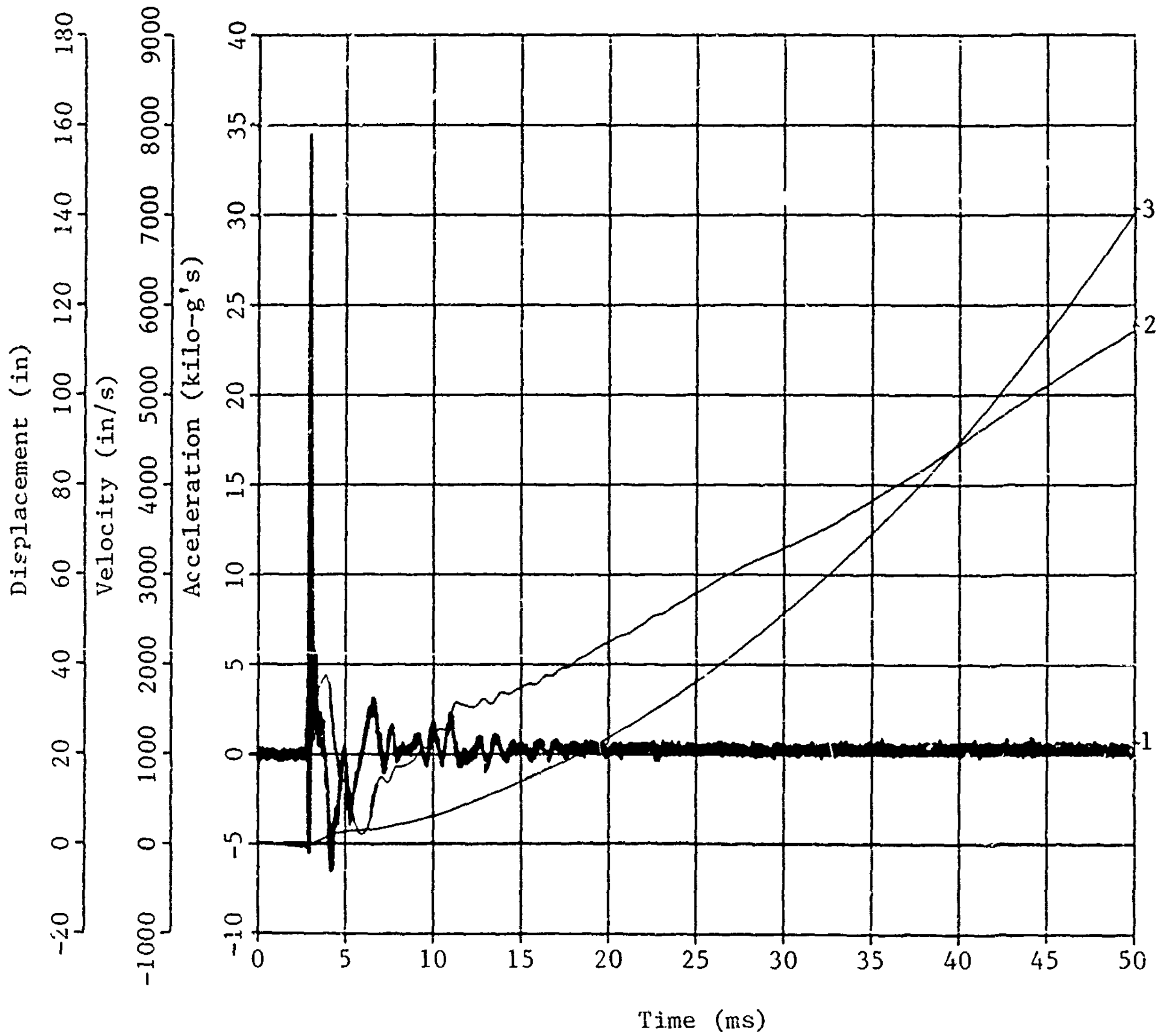


Figure 10. Record #8, vertical structure acceleration at 0.83' depth.

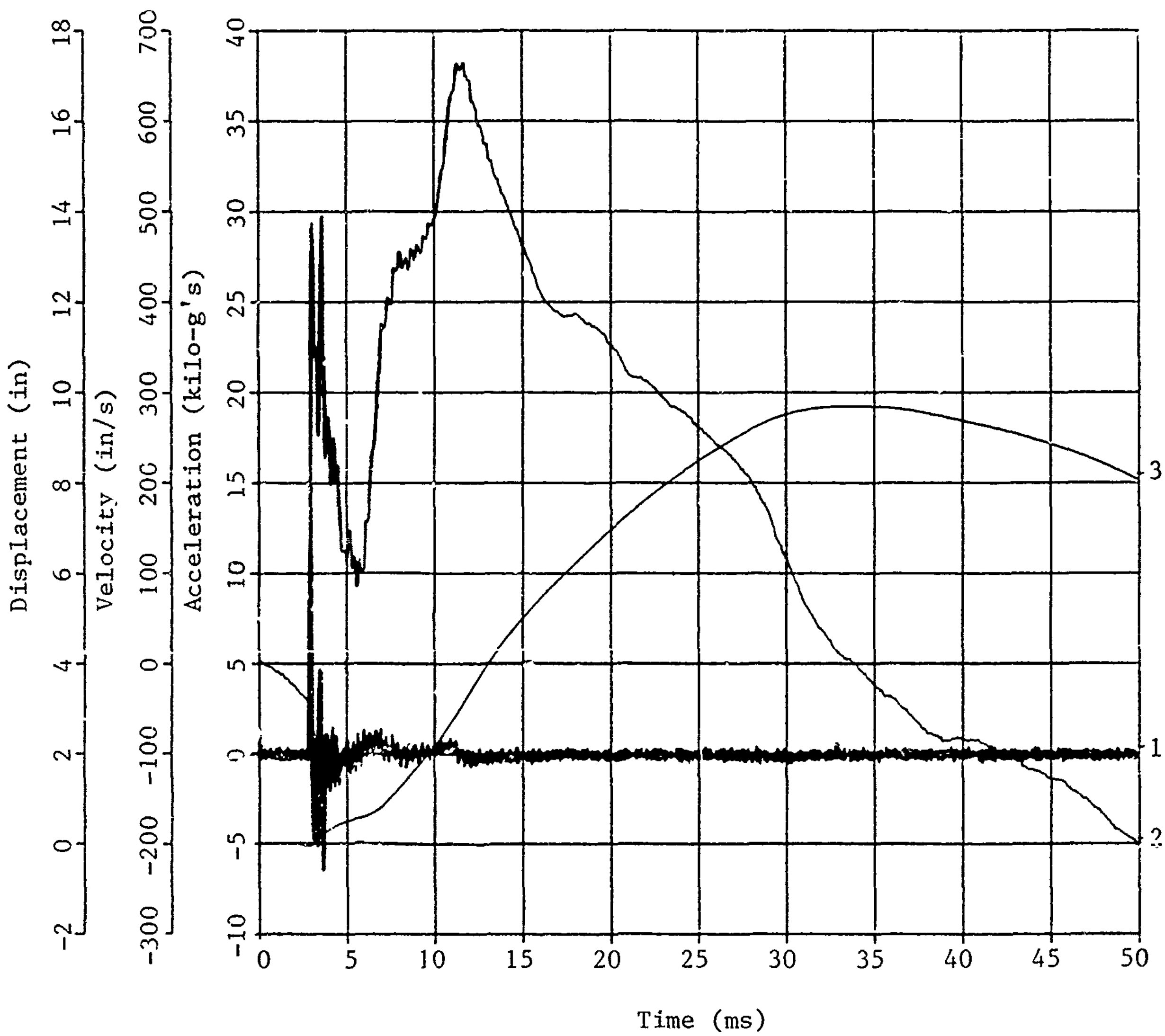


Figure 11. Record #9, vertical structure acceleration at 3.28' depth.

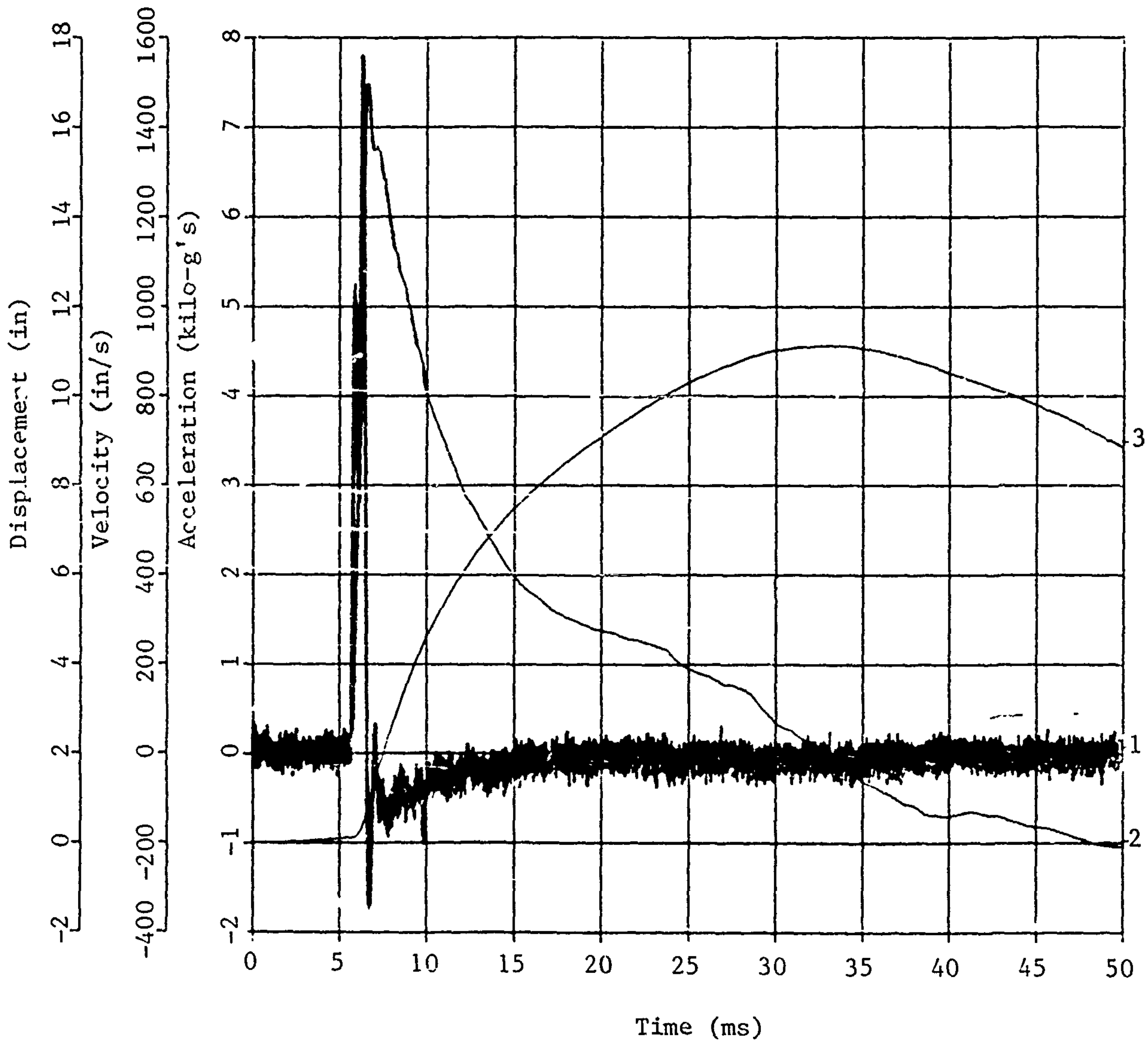


Figure 12. Record #10, vertical soil acceleration at 5.21' depth.

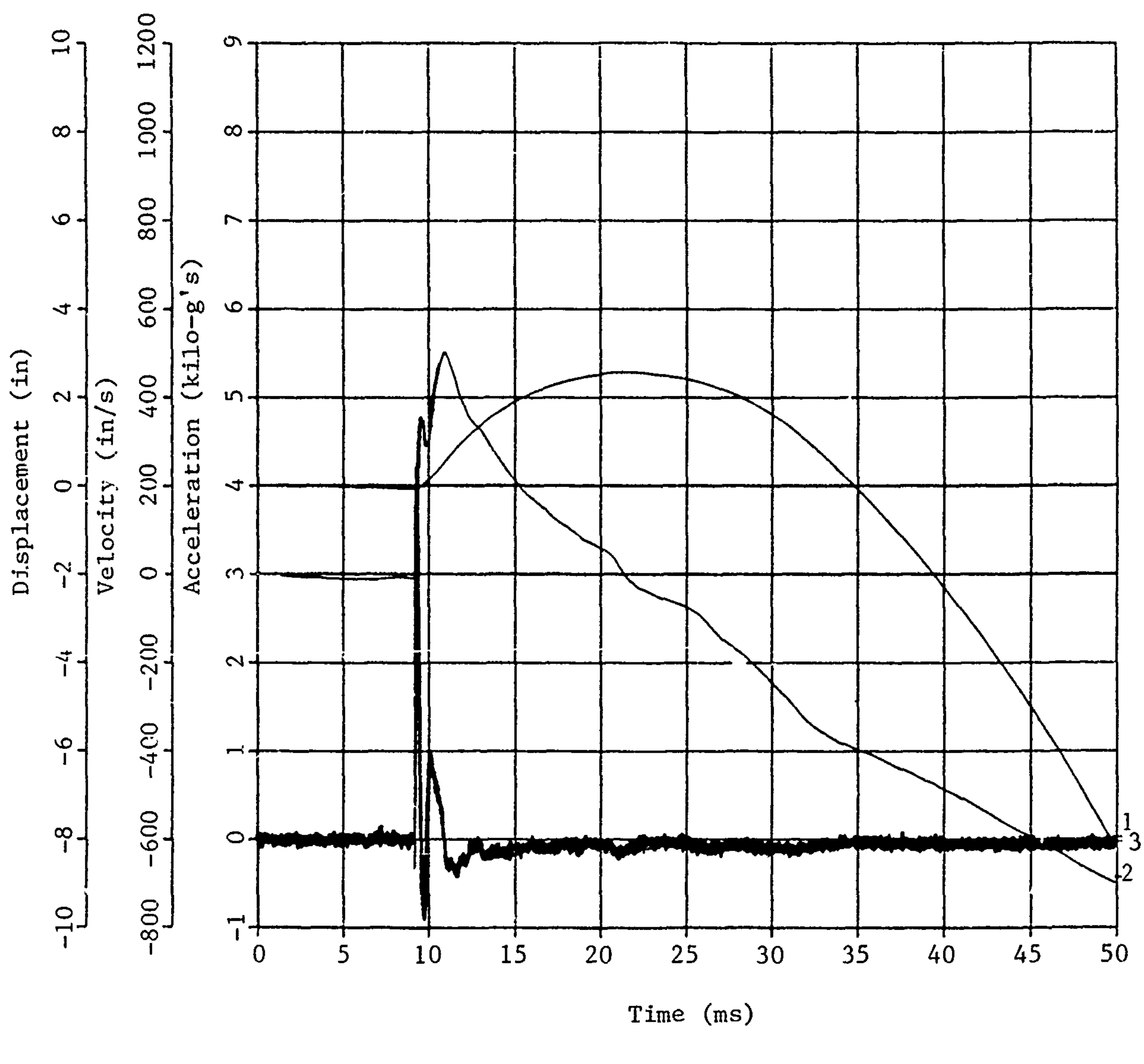


Figure 13. Record #11, vertical soil acceleration at 12.21' depth.

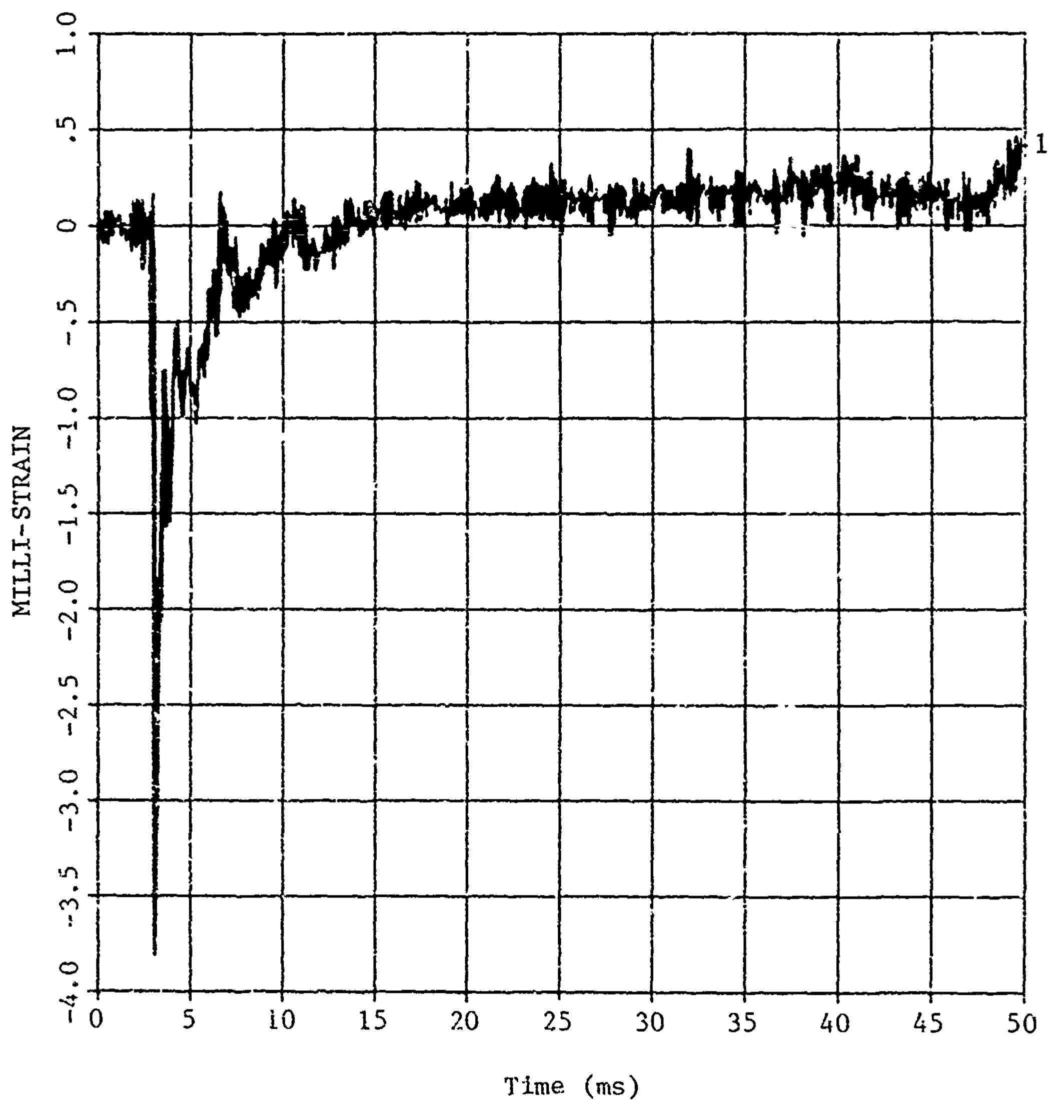


Figure 14. Record #12, vertical structural strain at 1.29' depth.

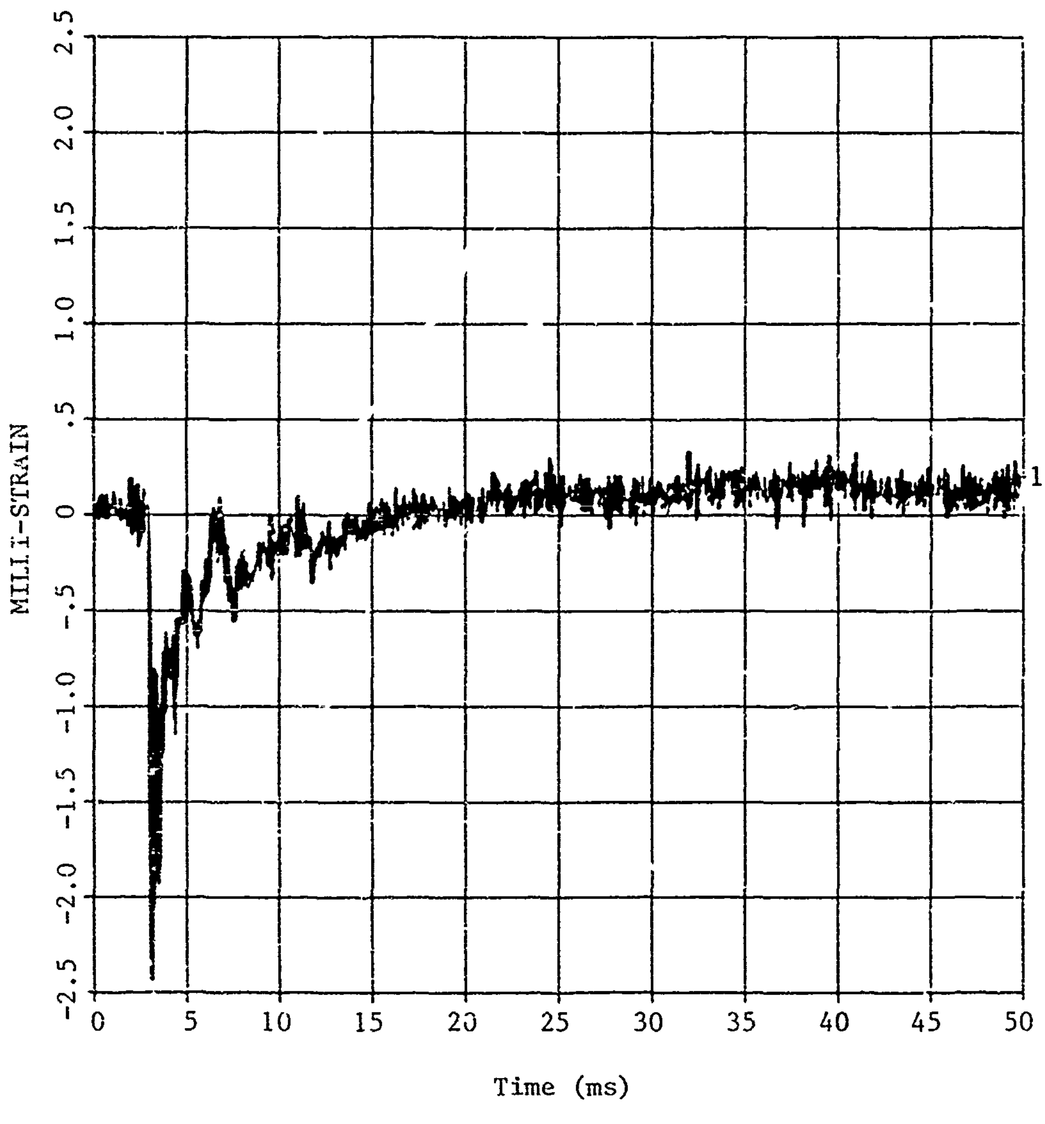


Figure 15. Record #13, vertical structural strain at 1.29' depth.

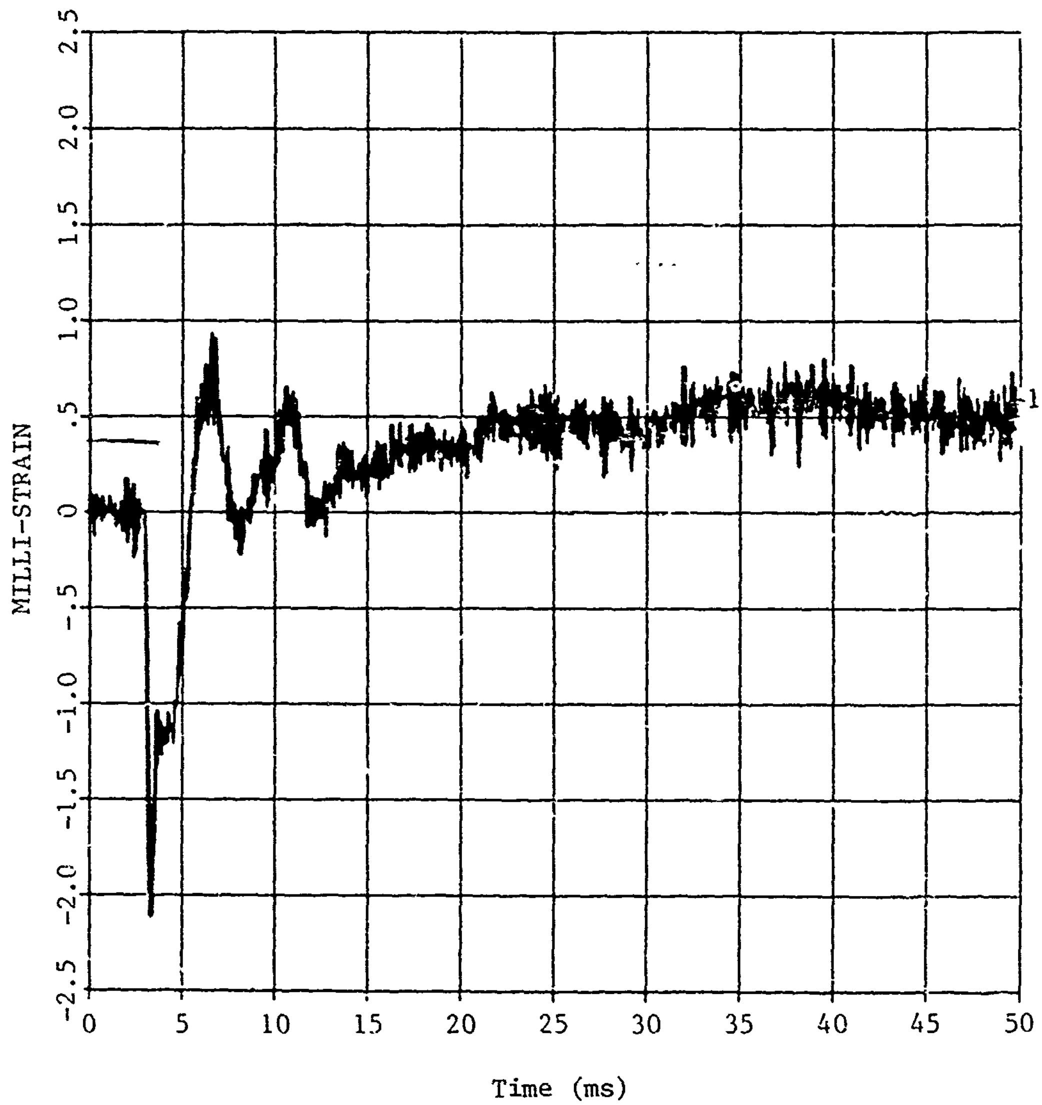


Figure 15. Record #14, vertical structural strain at 3.33' depth.

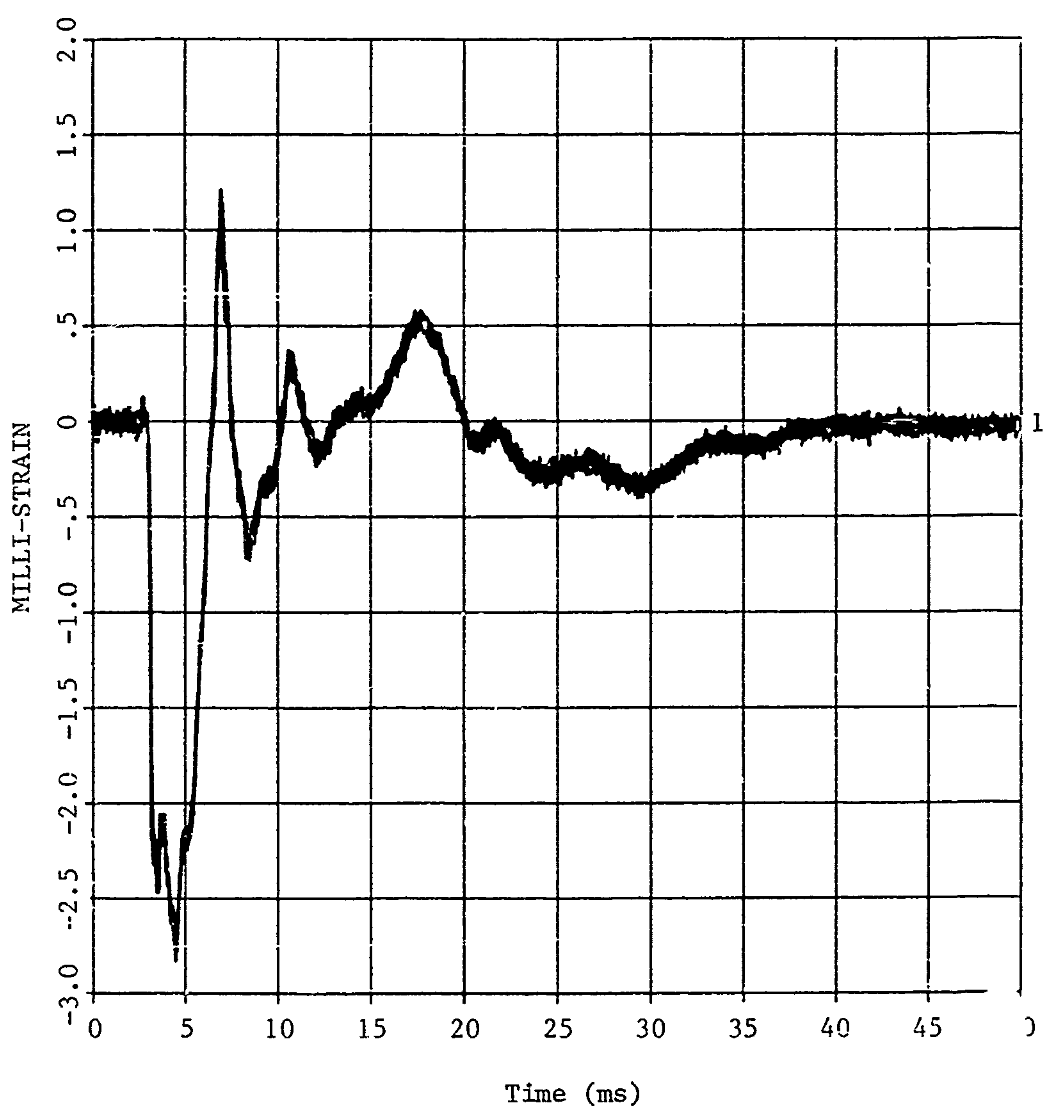


Figure 17. Record #15, vertical structural strain at 5.21' depth.

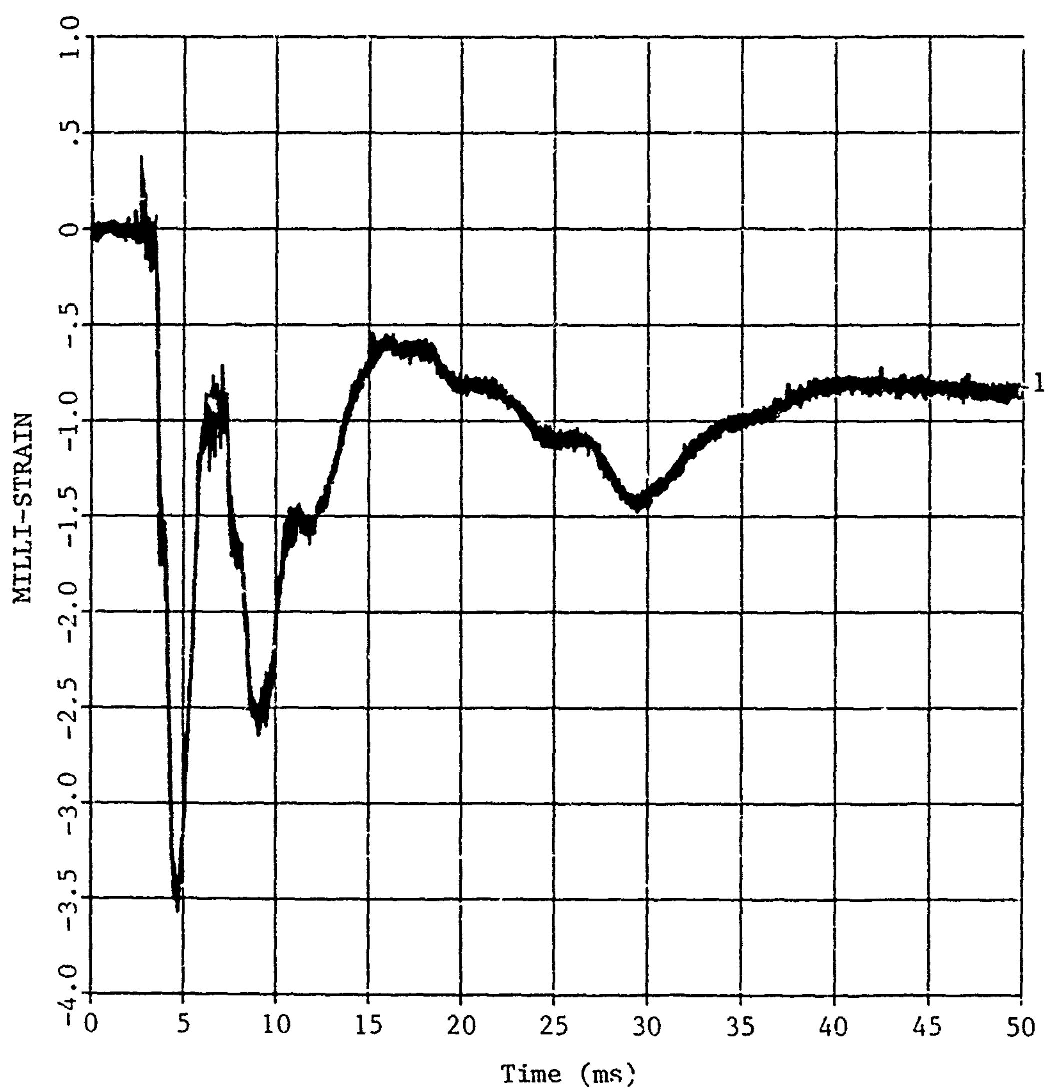


Figure 18. Record #16, vertical structural strain at 12.21' depth.

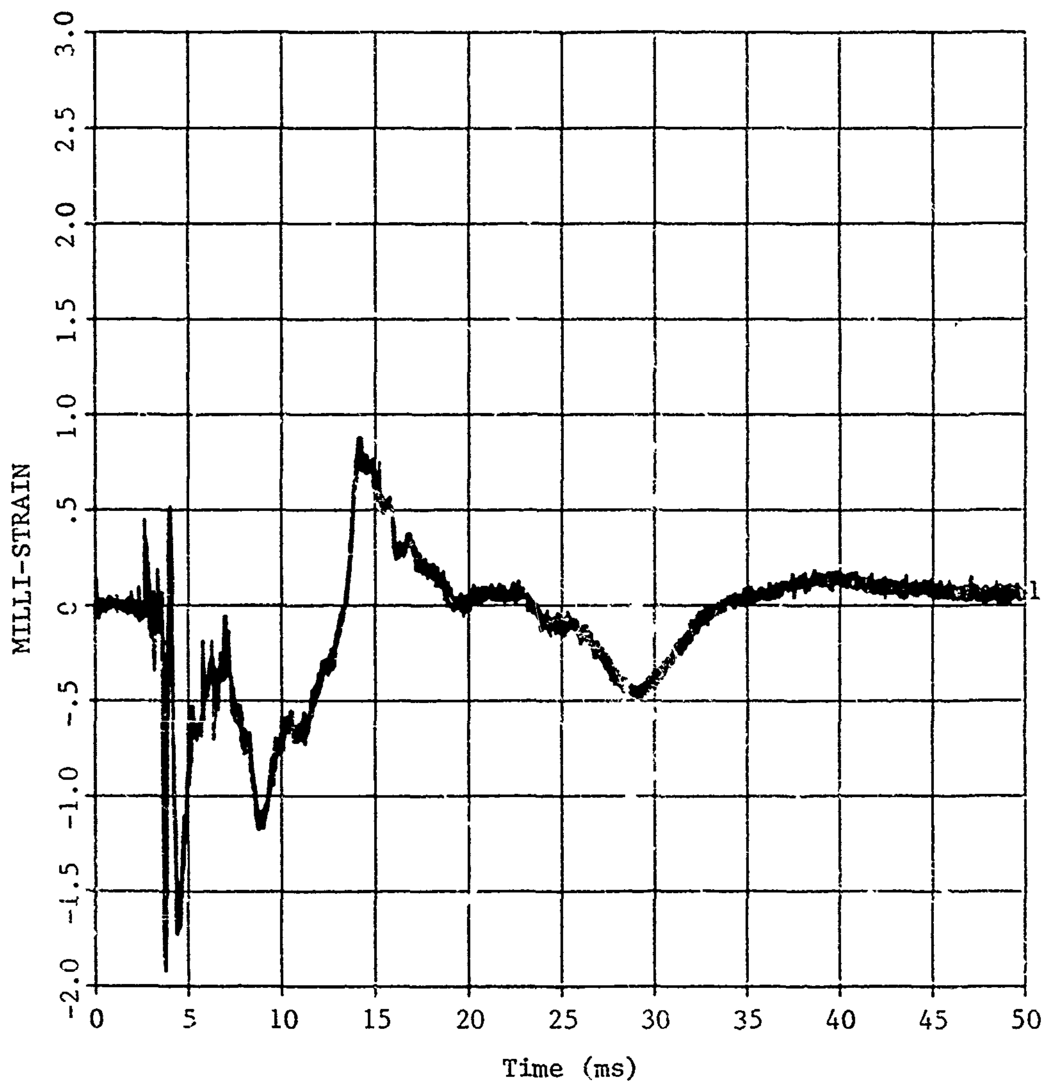


Figure 19. Record #17, vertical structural strain at 18.71' depth.

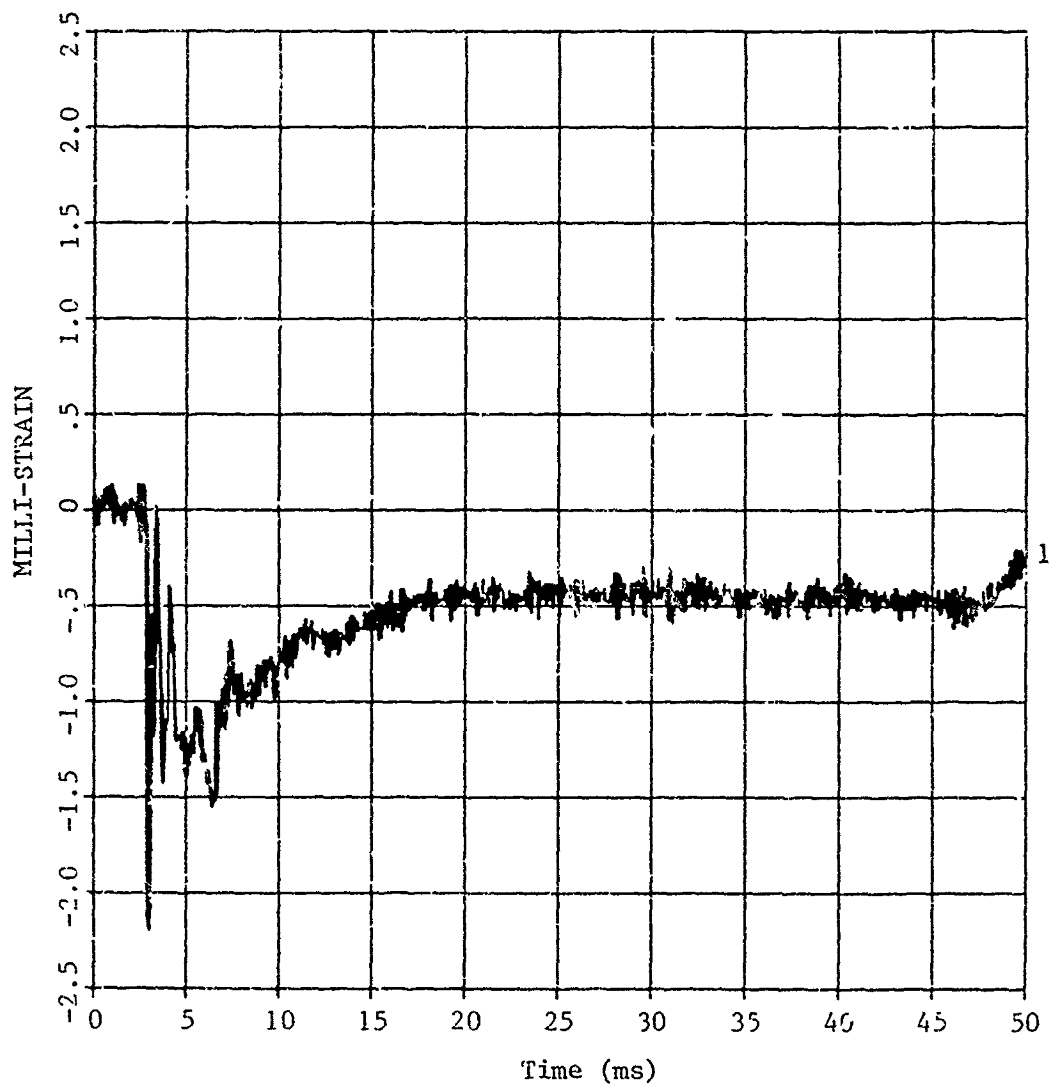


Figure 20. Record #18, structural hoop strain at 1.29' depth.

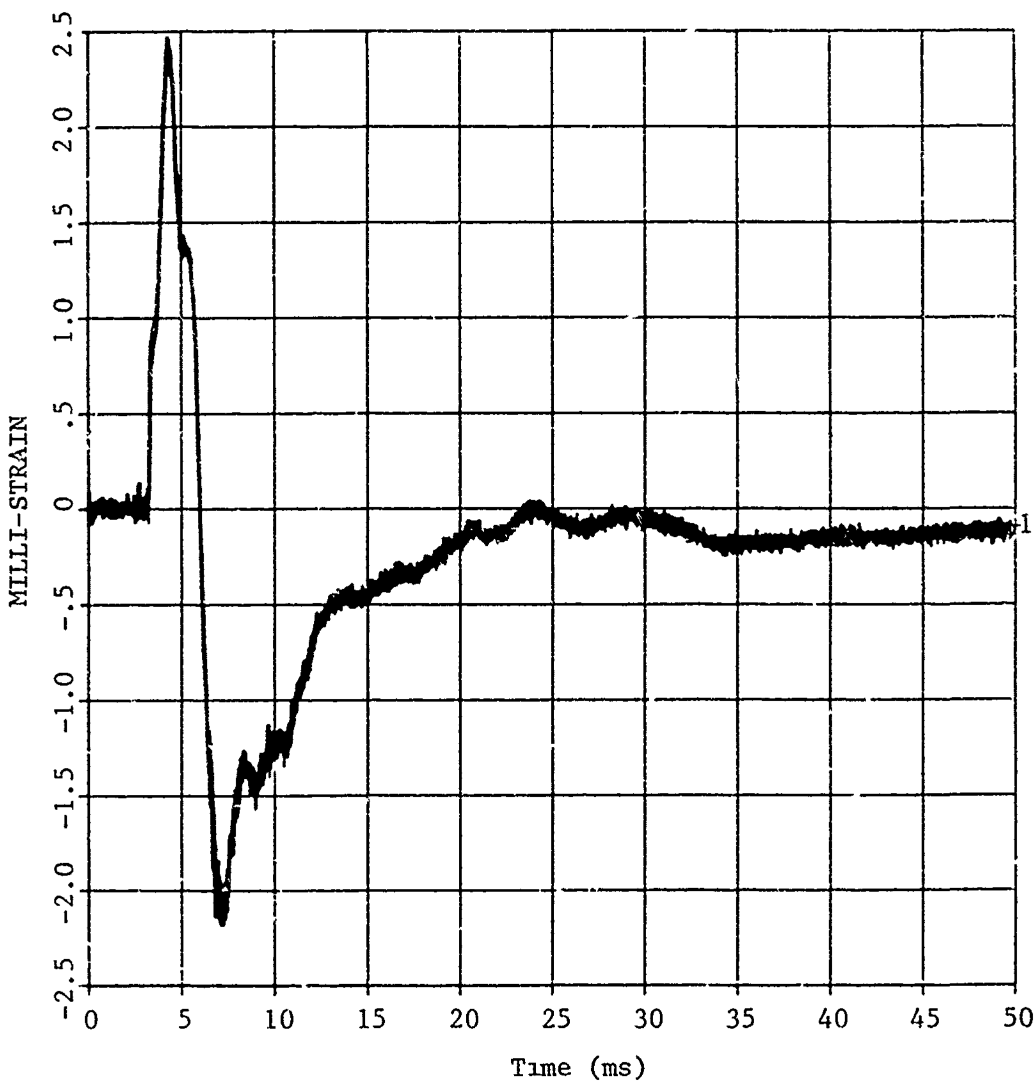


Figure 21. Record #19, structural hoop strain at 5.29' depth.

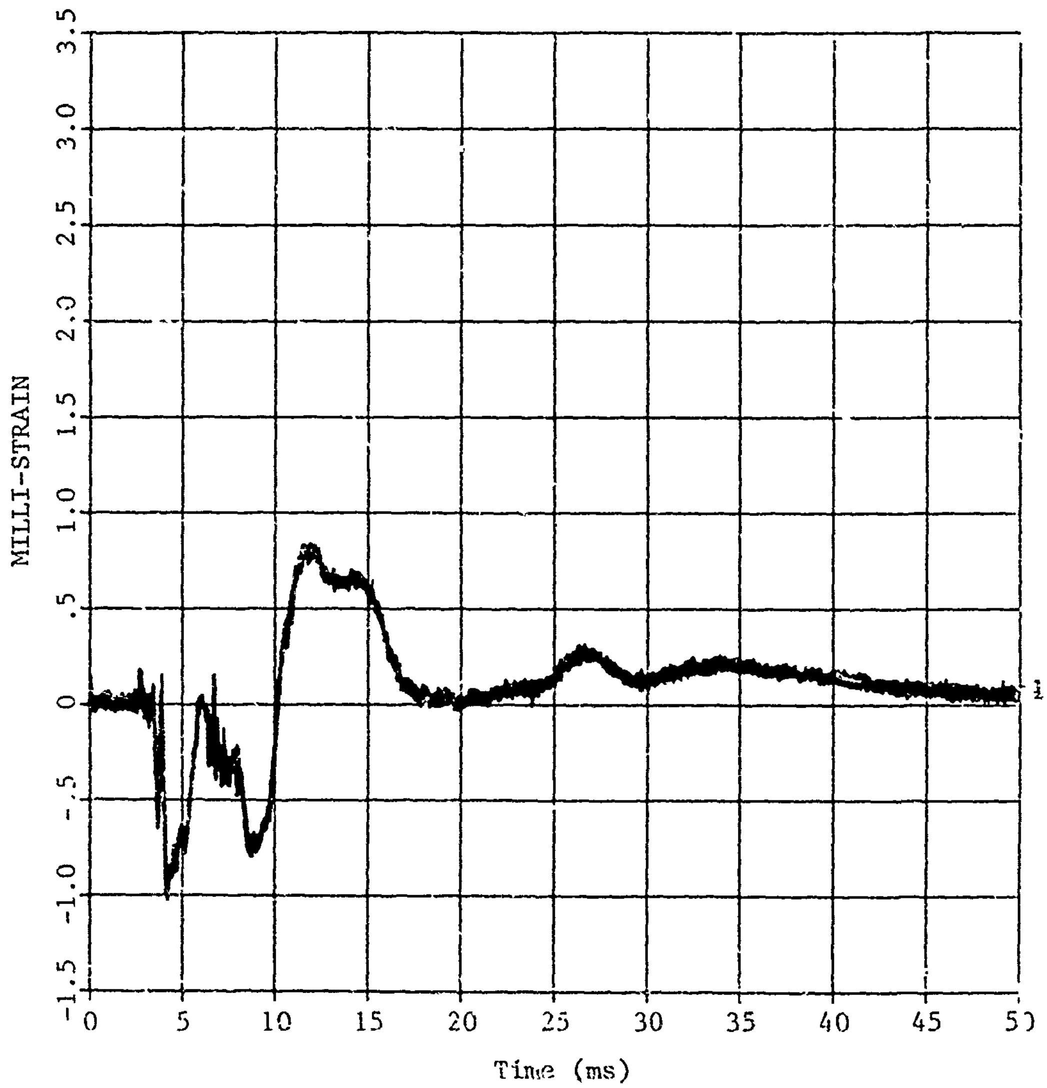


Figure 22. Record #20, structural hoop strain at 12.21' depth.

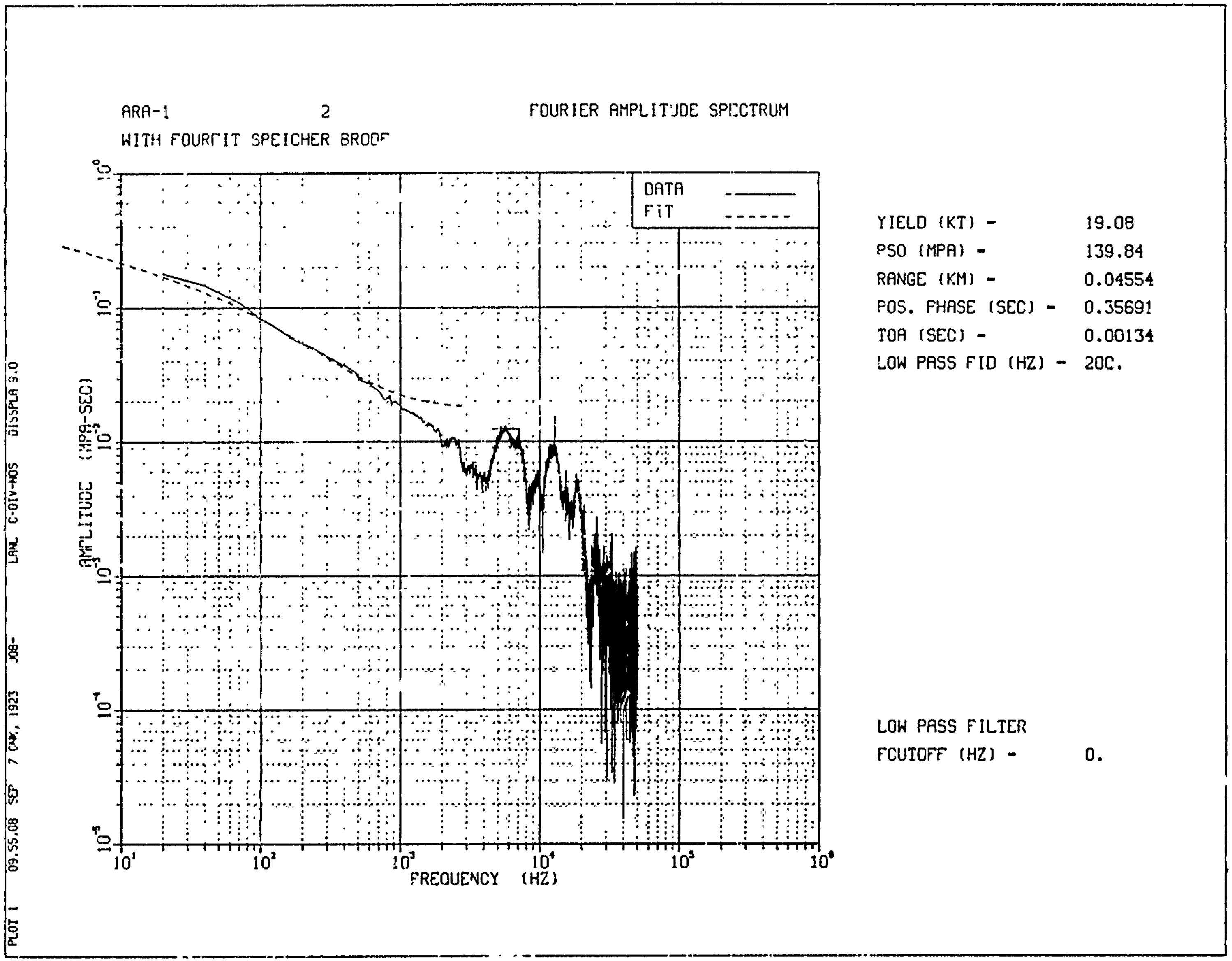


Figure 23a. FFT fit comparison for test data record #2.

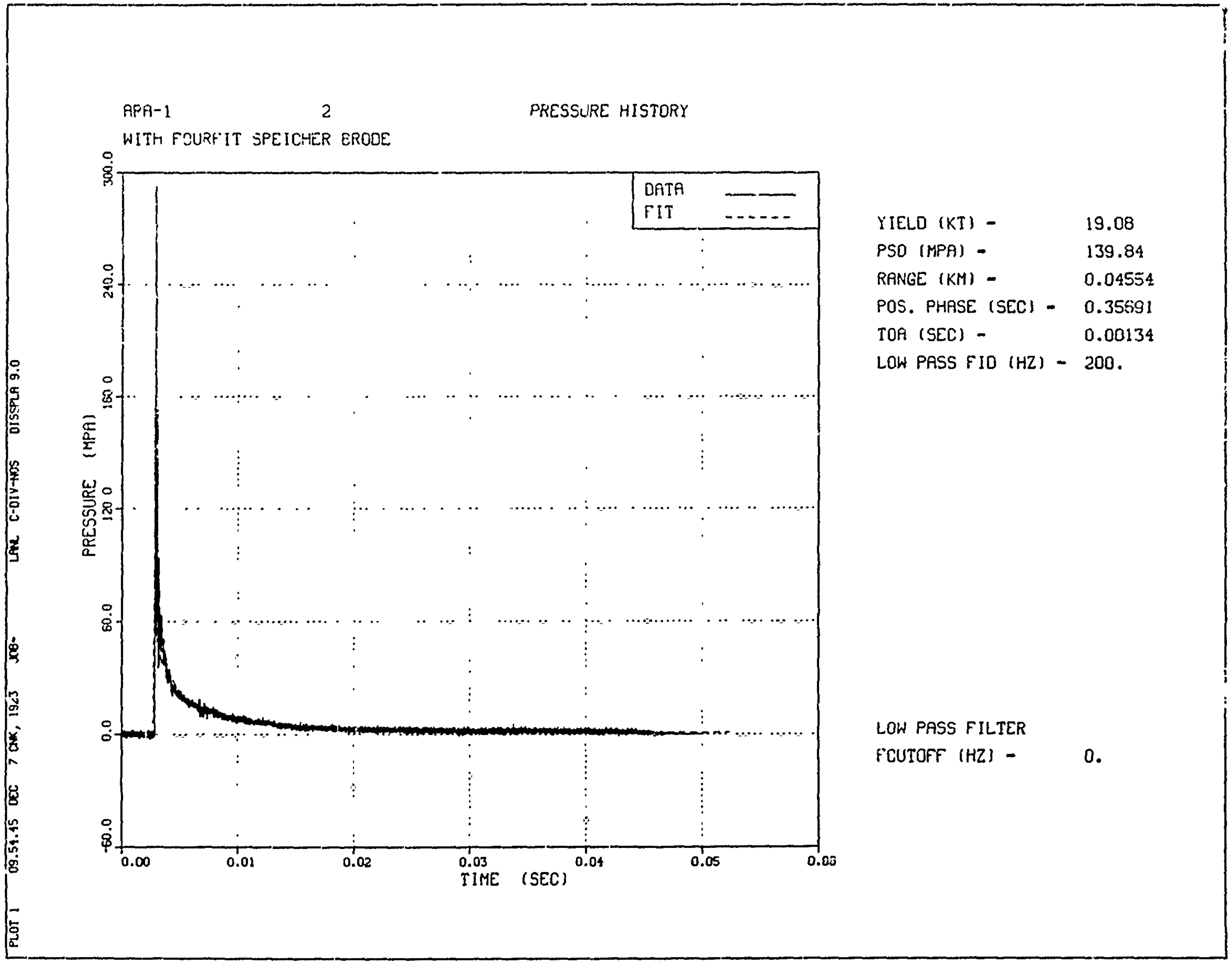


Figure 23b. Time history comparison of Speicher-Brode waveform to HEST record #2.

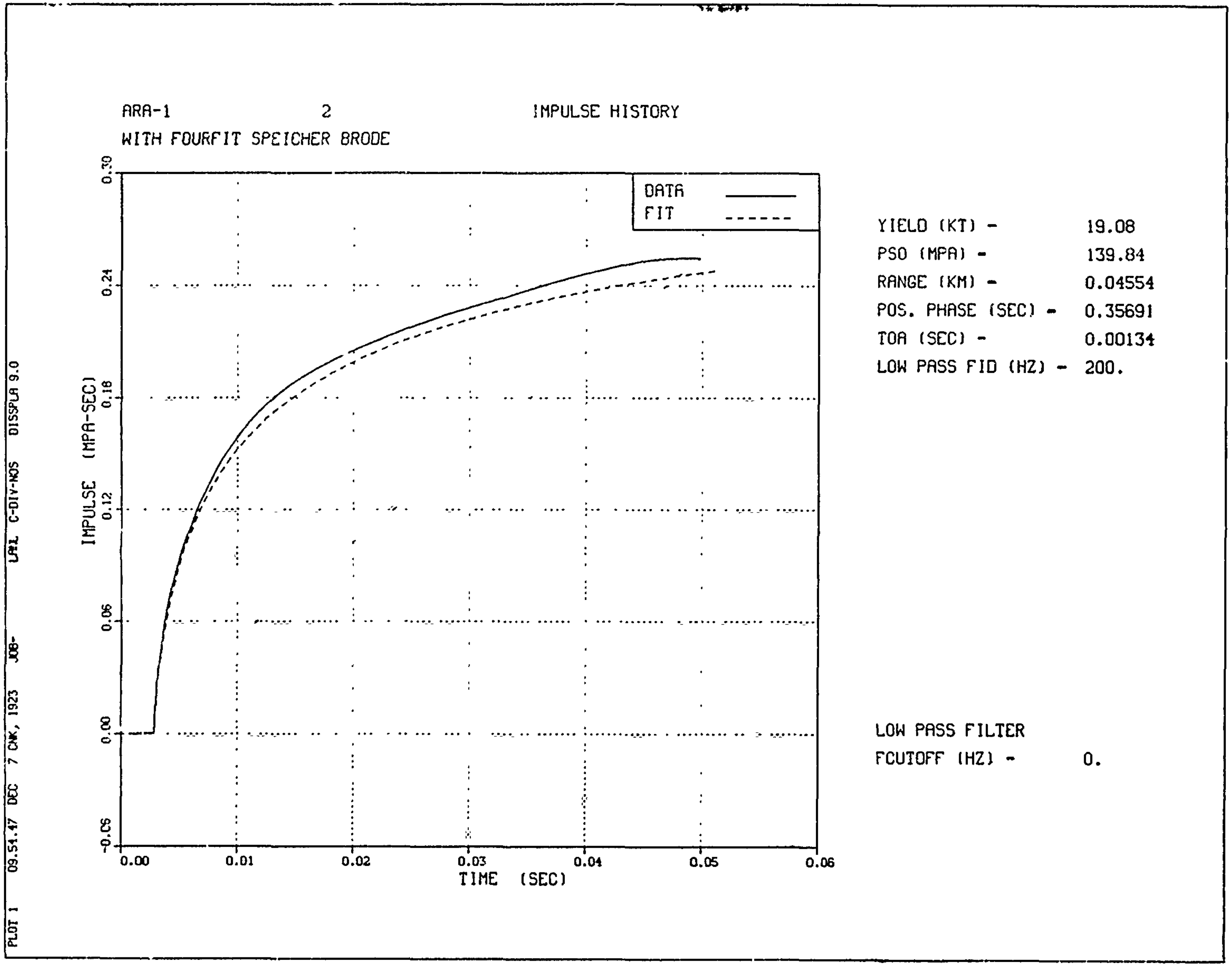


Figure 23c. Impulse time history comparison for record #2.

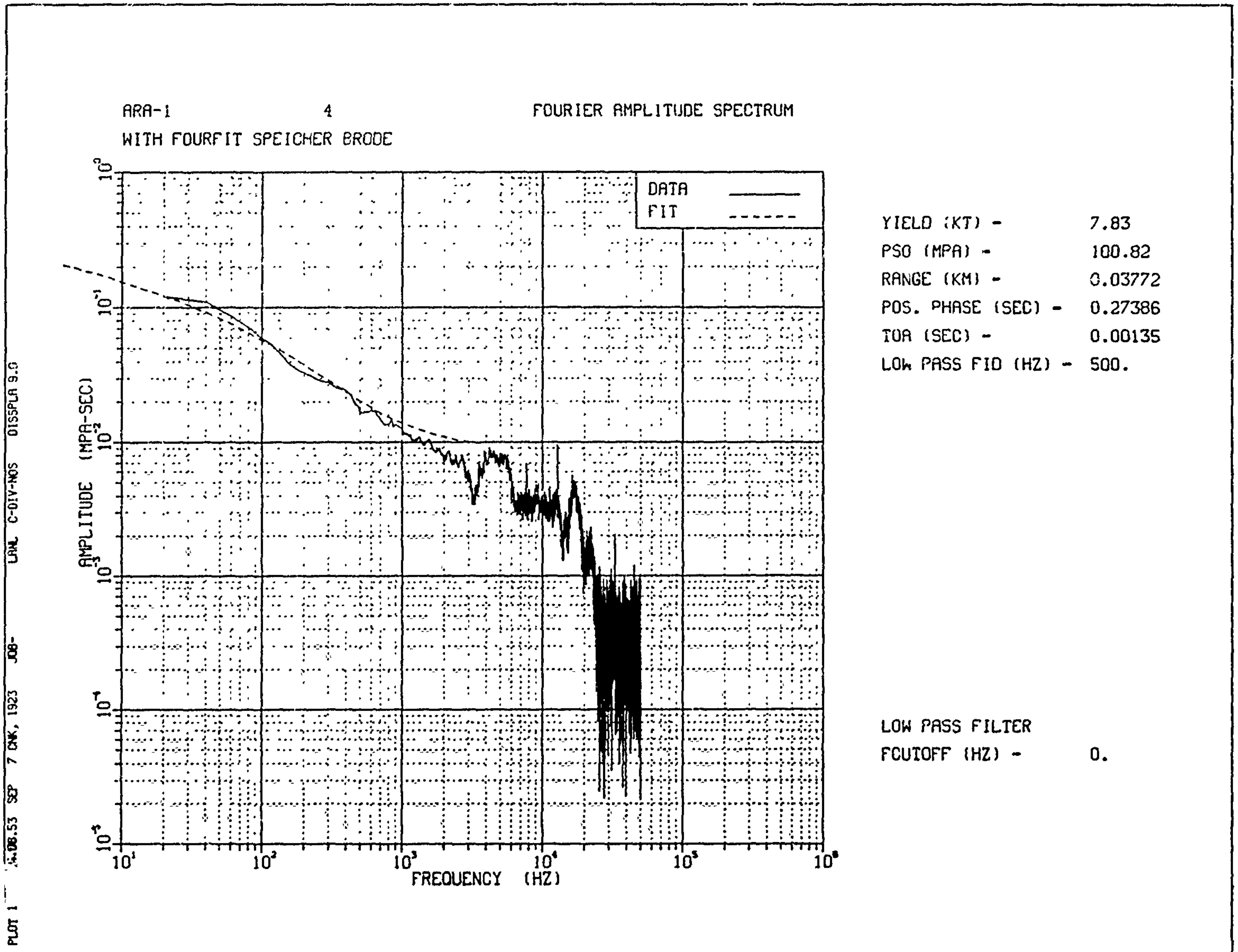


Figure 24a. FFT fit comparison for test data record #4.

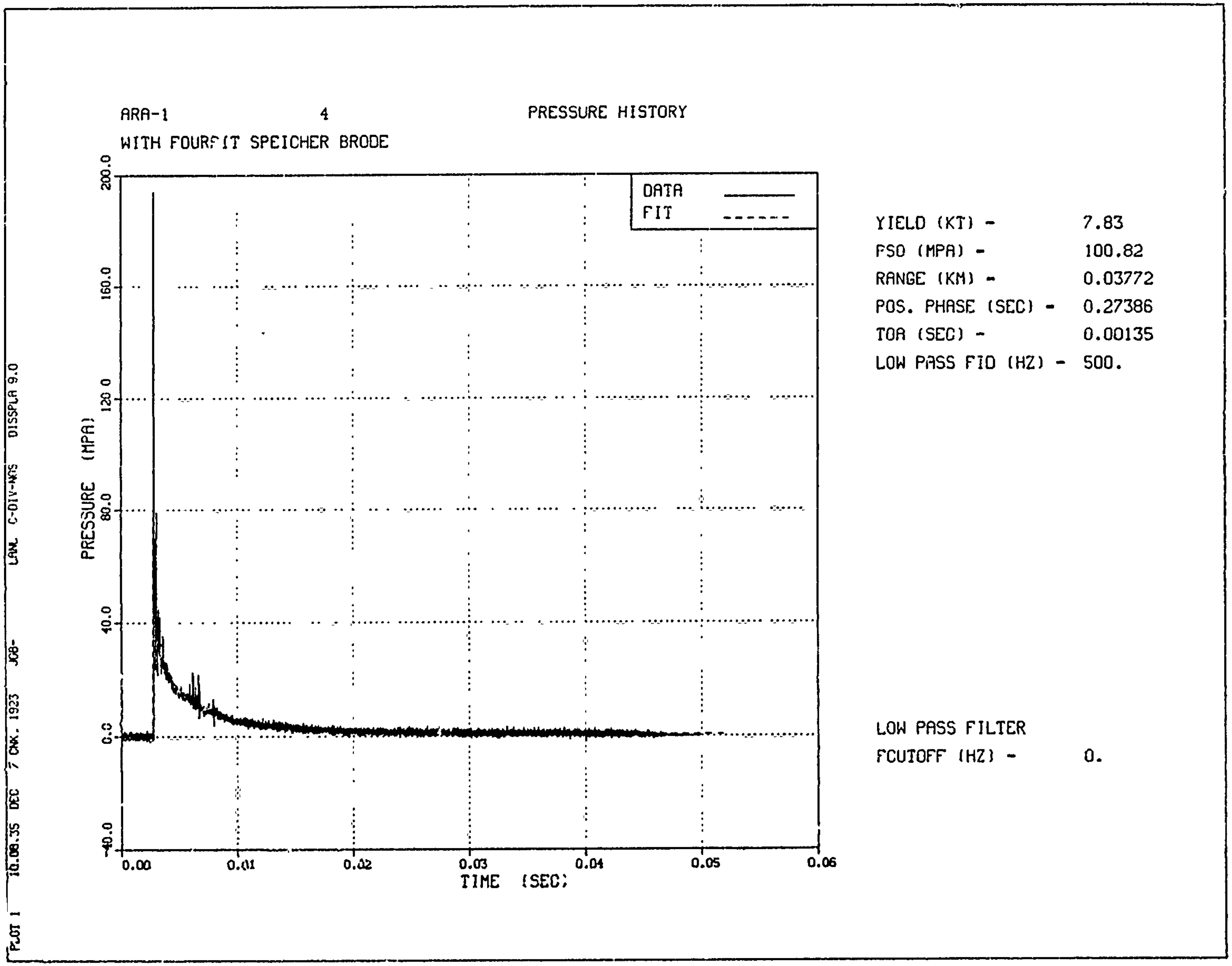


Figure 24b. Time history of Speicher-Brode waveform to HEST record #4.

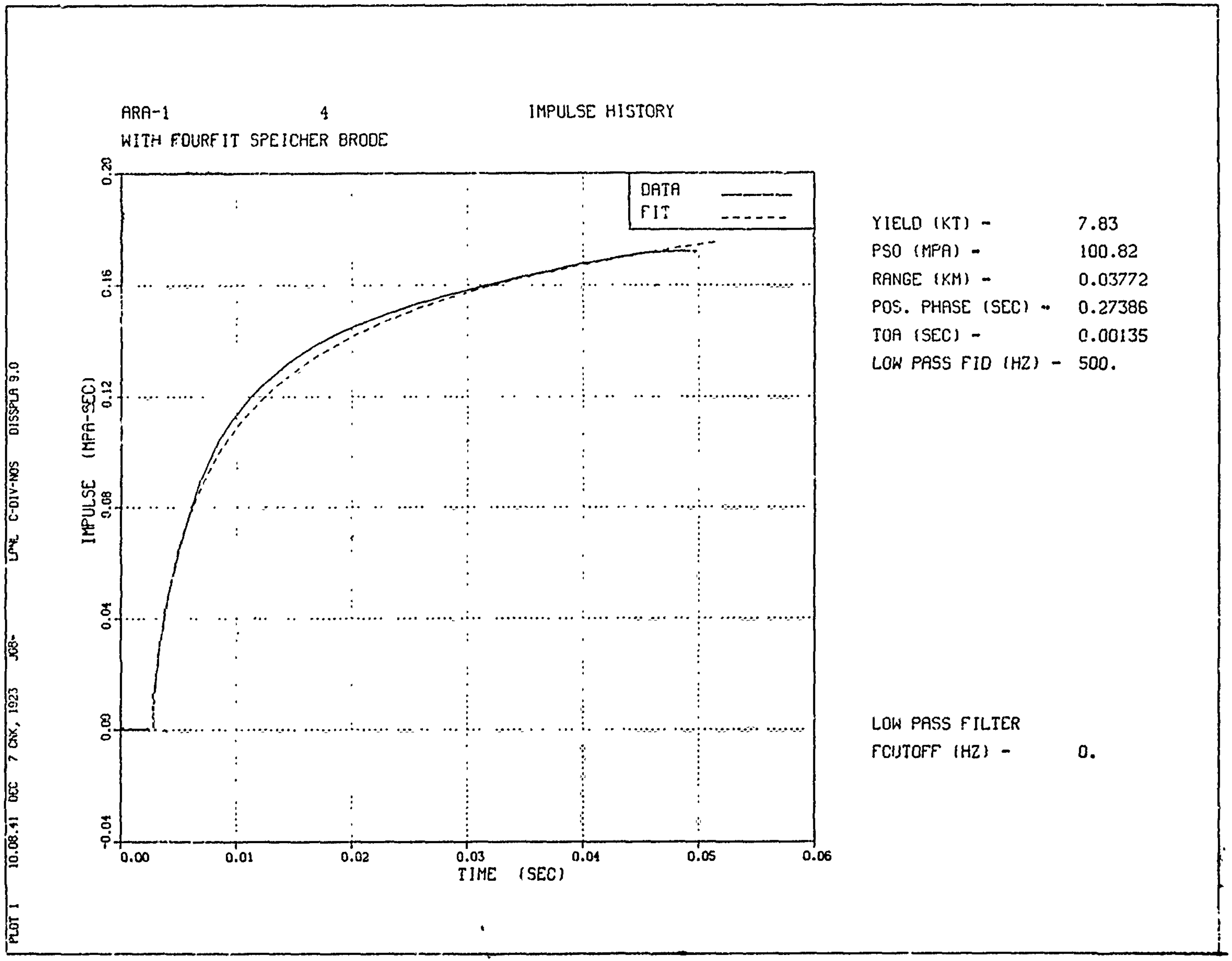


Figure 24c. Impulse time history comparison for record #4.

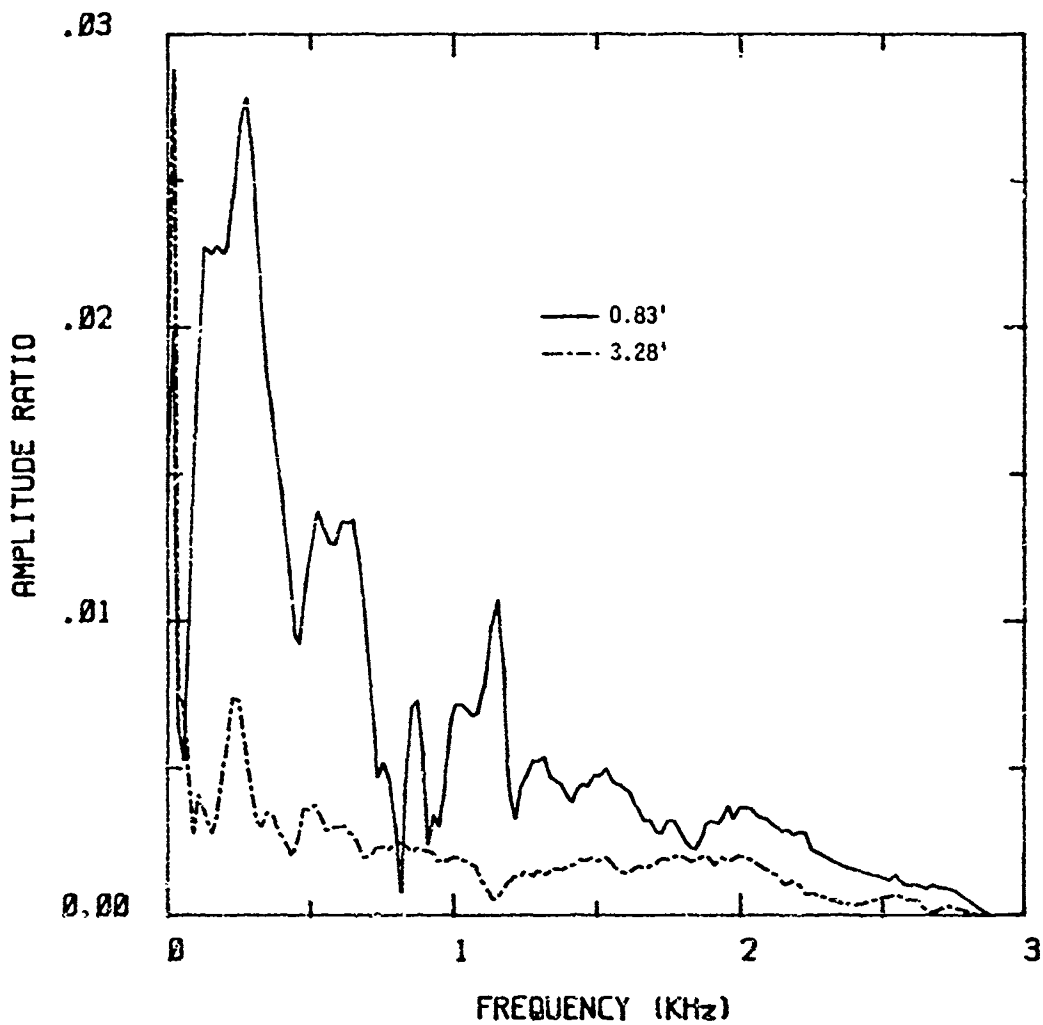


Figure 25. FRF's for vertical soil stress (0.5' and 5.21').

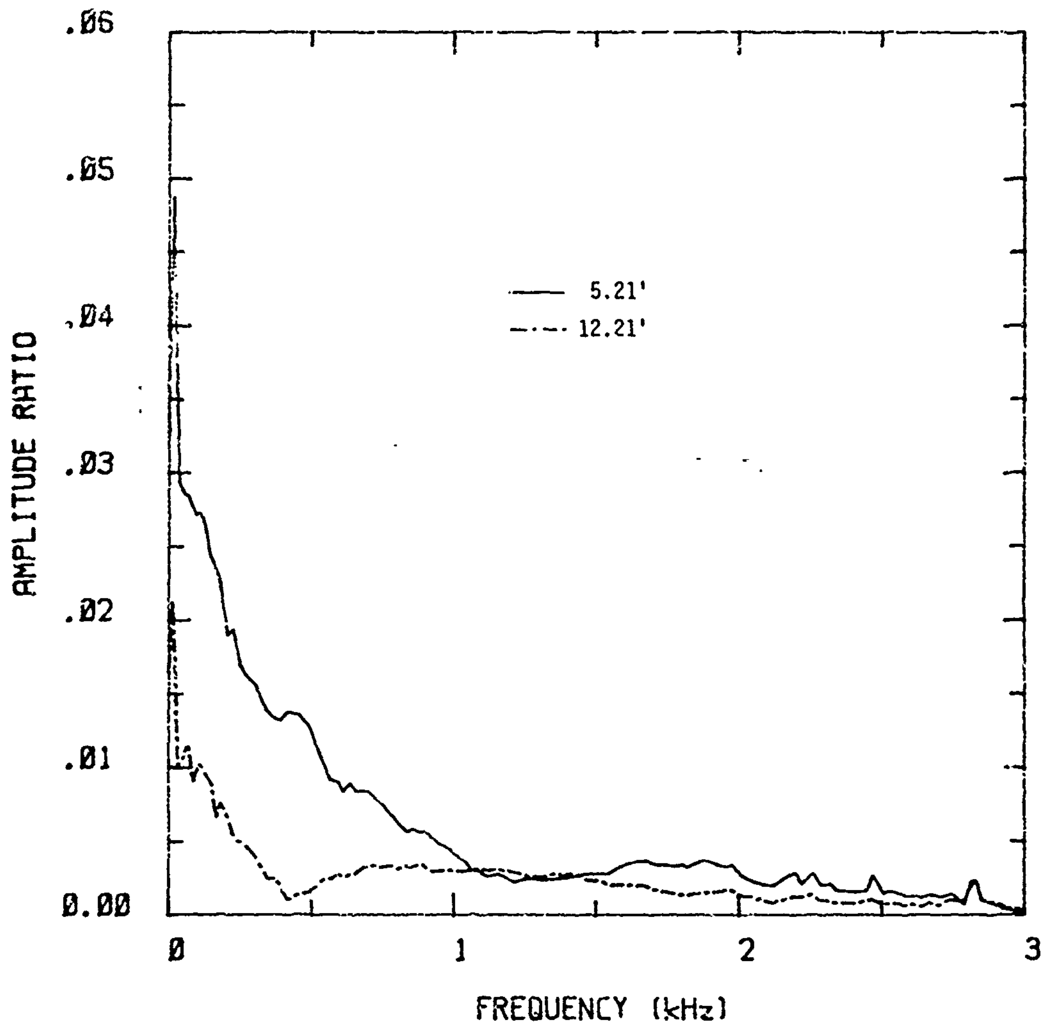


Figure 26. FRF's for vertical soil velocity (5.21' and 12.21').

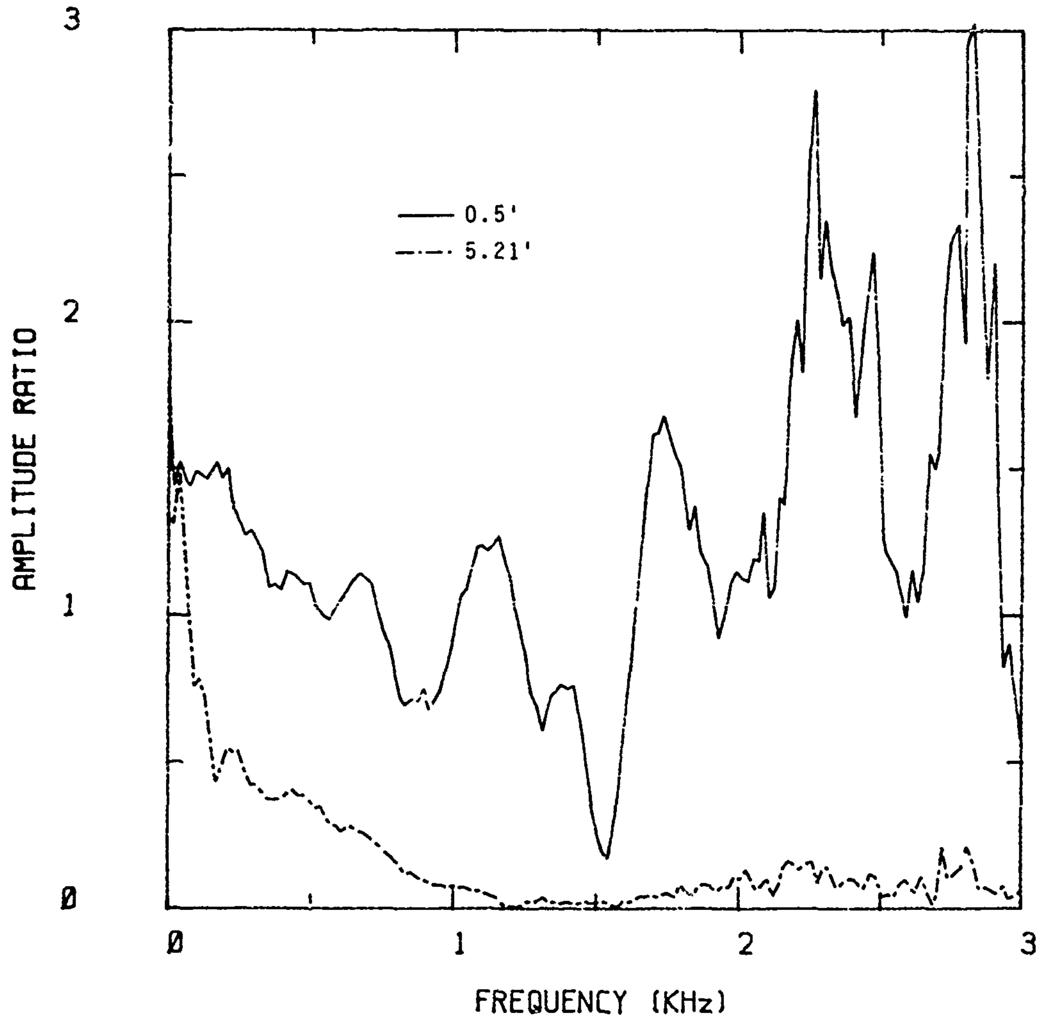


Figure 27. FRF's for vertical structural velocities (0.83' and 3.28').

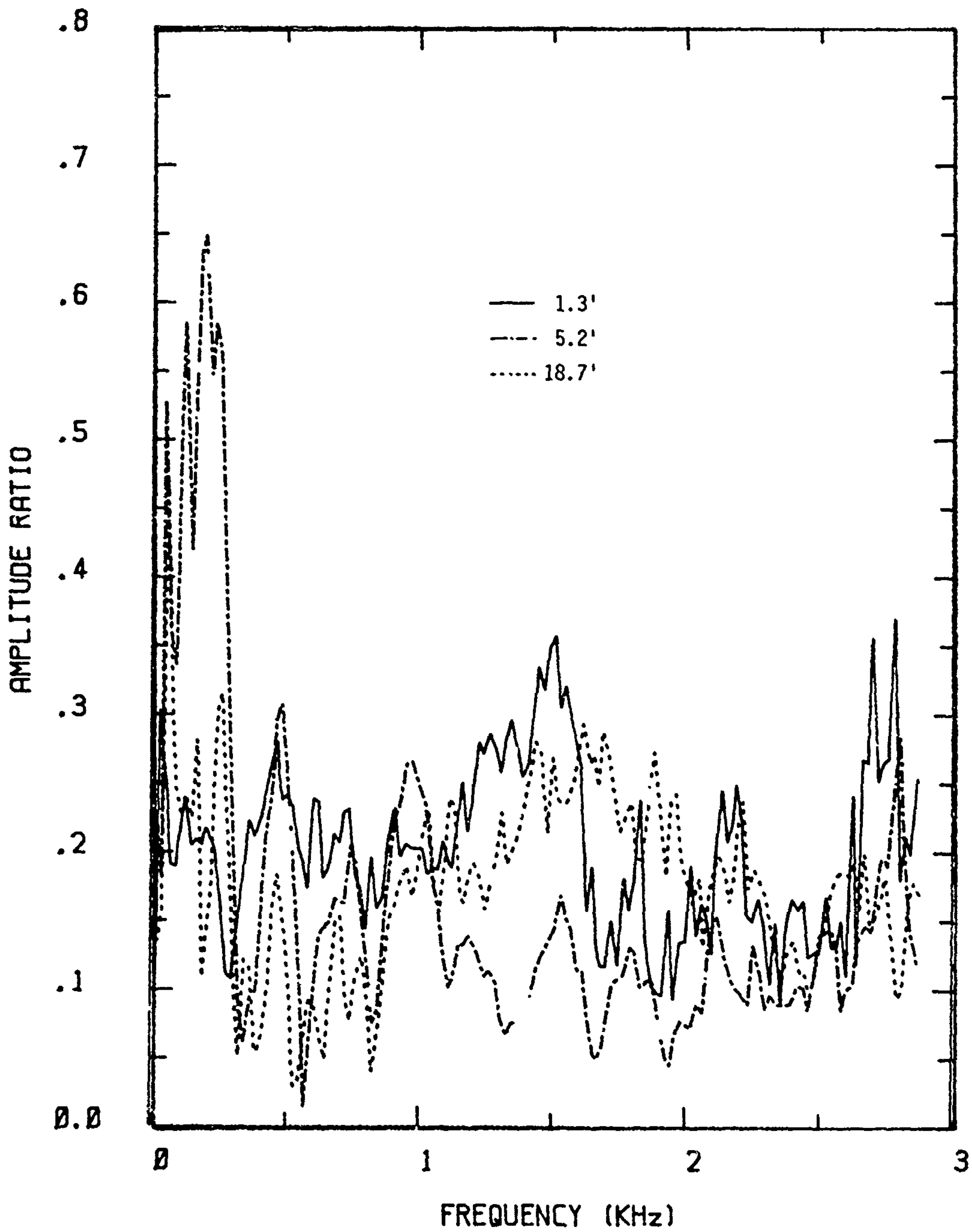


Figure 28. FRF's for vertical structural strains (1.3', 5.2', and 18.7').

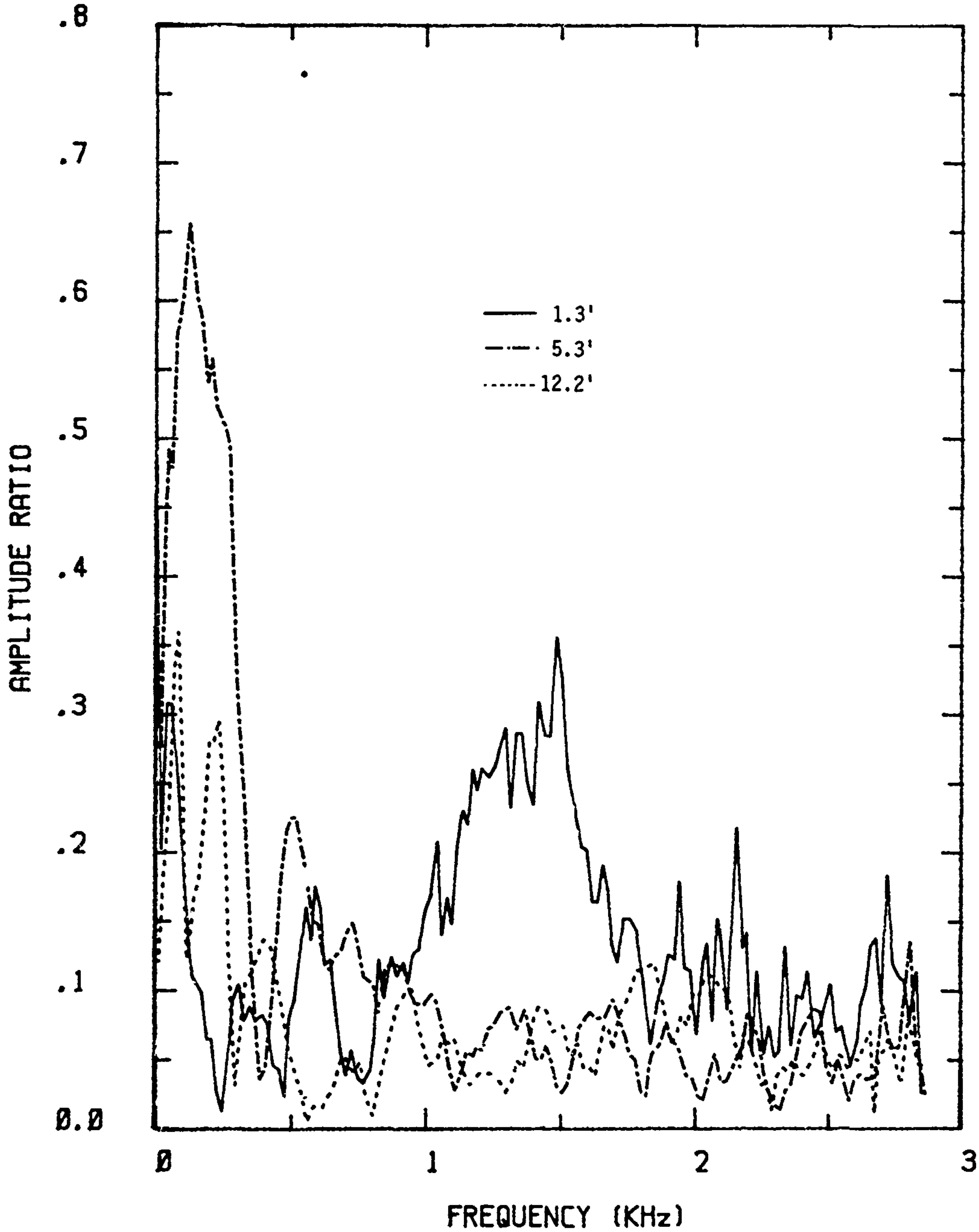


Figure 29. FRF's for structural hoop strains (1.3', 5.3', and 12.2').

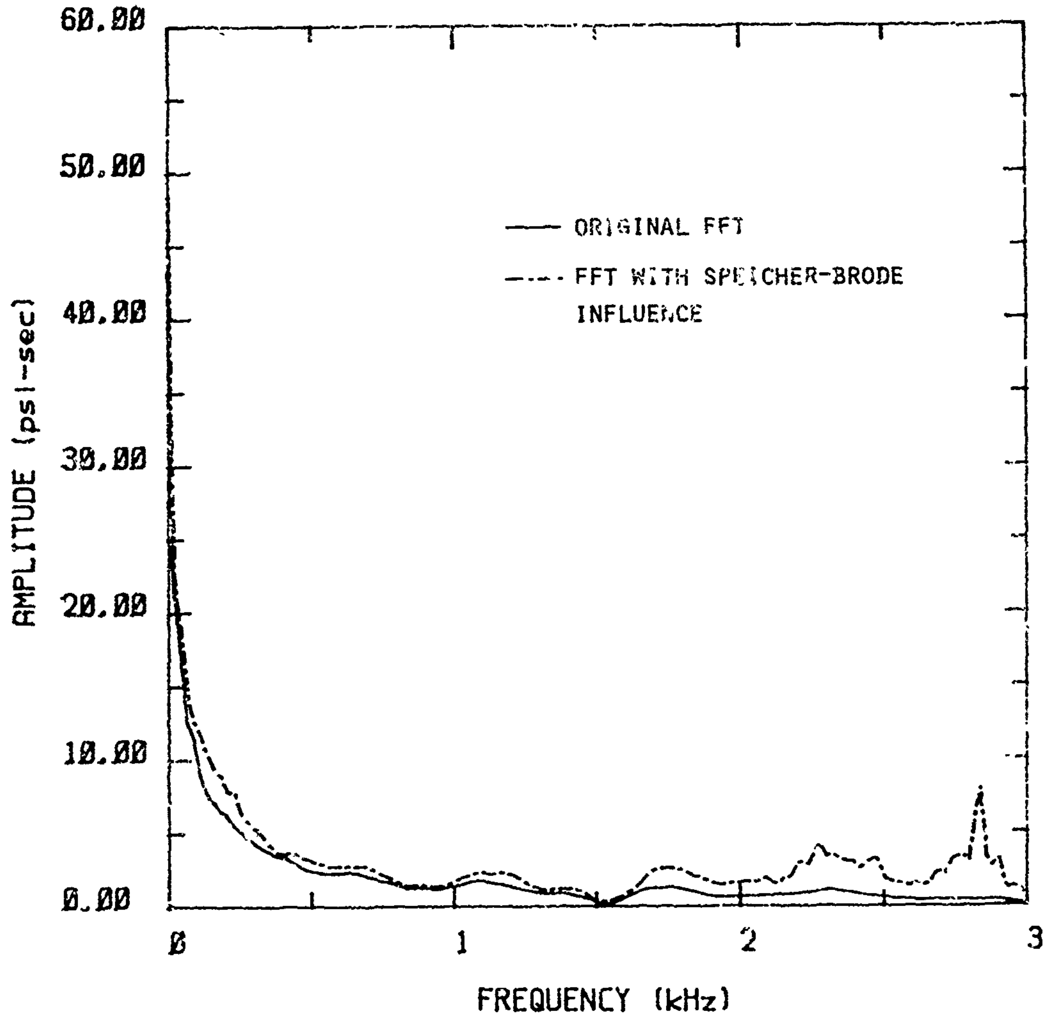


Figure 30. Comparison of original FFT to FFT with Speicher-Brode influence for record #6.

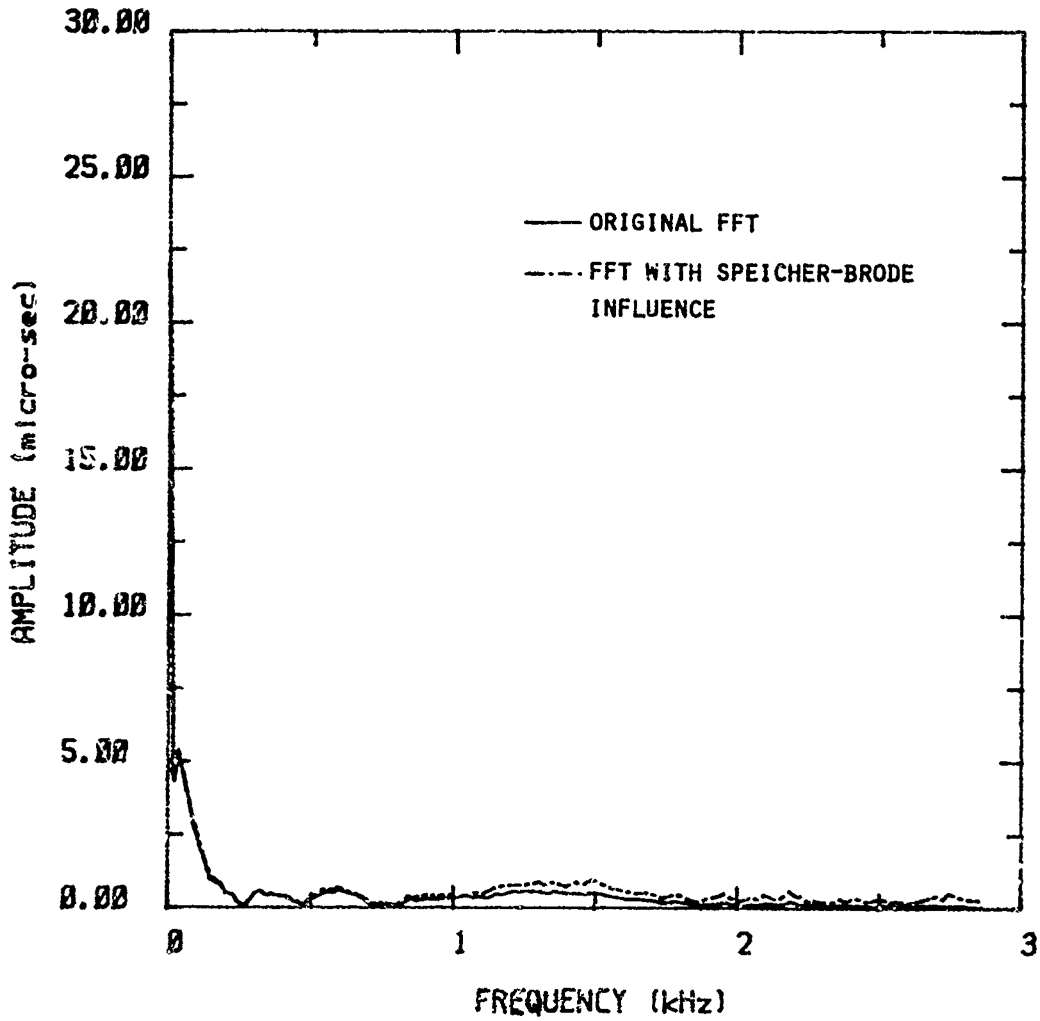
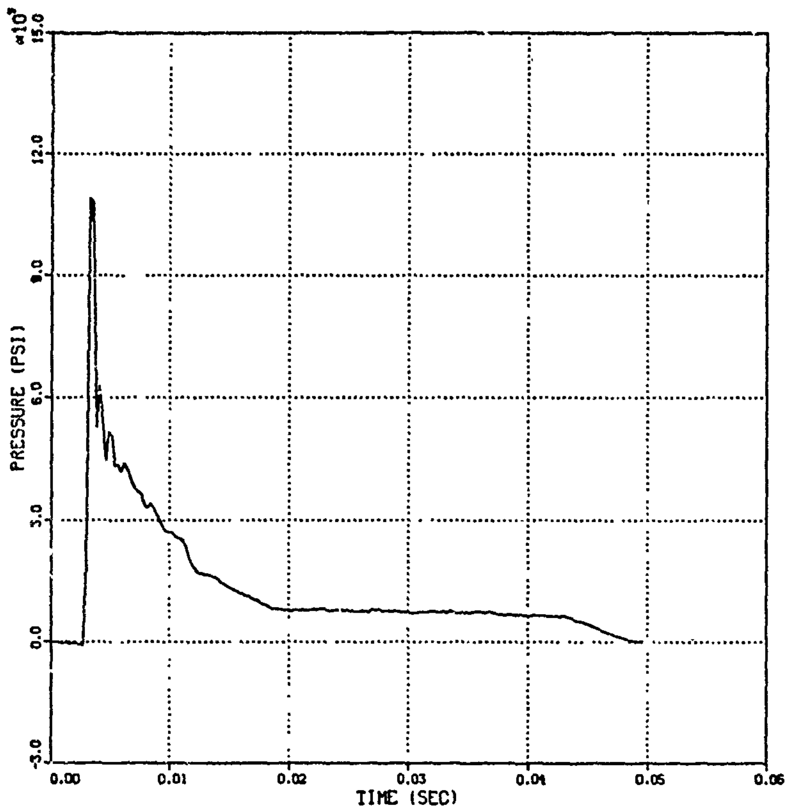
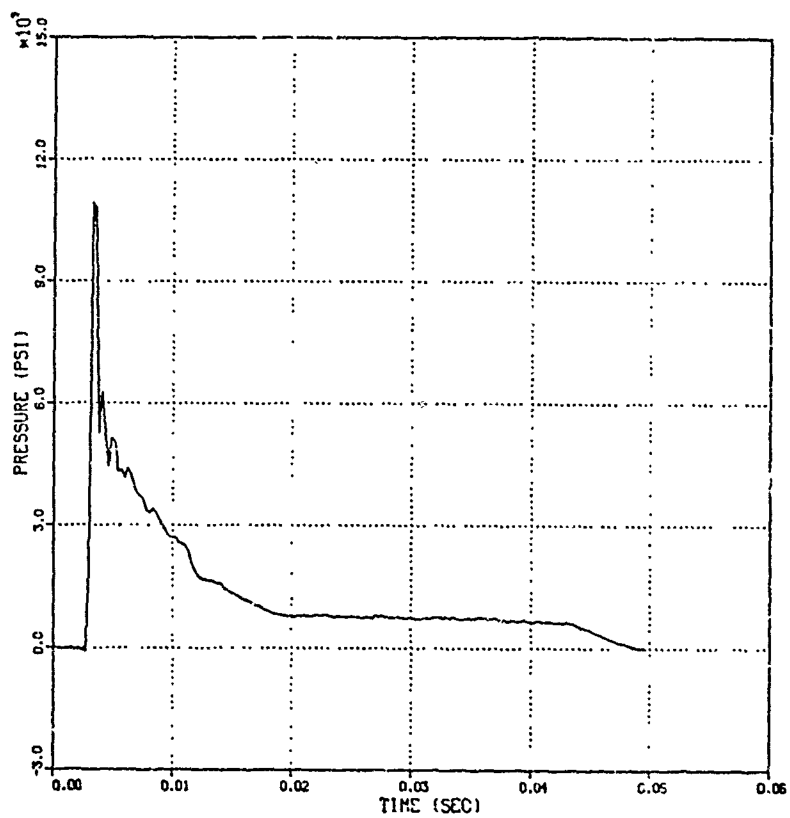


Figure 31. Comparison of original FFT to FFT with Speicher-Brode influence for record #18.



(a) Original time history (from direct inverse FFT)



(b) Time history with Speicher-Brode influence

Figure 32. Record Number 5 Time History Comparison

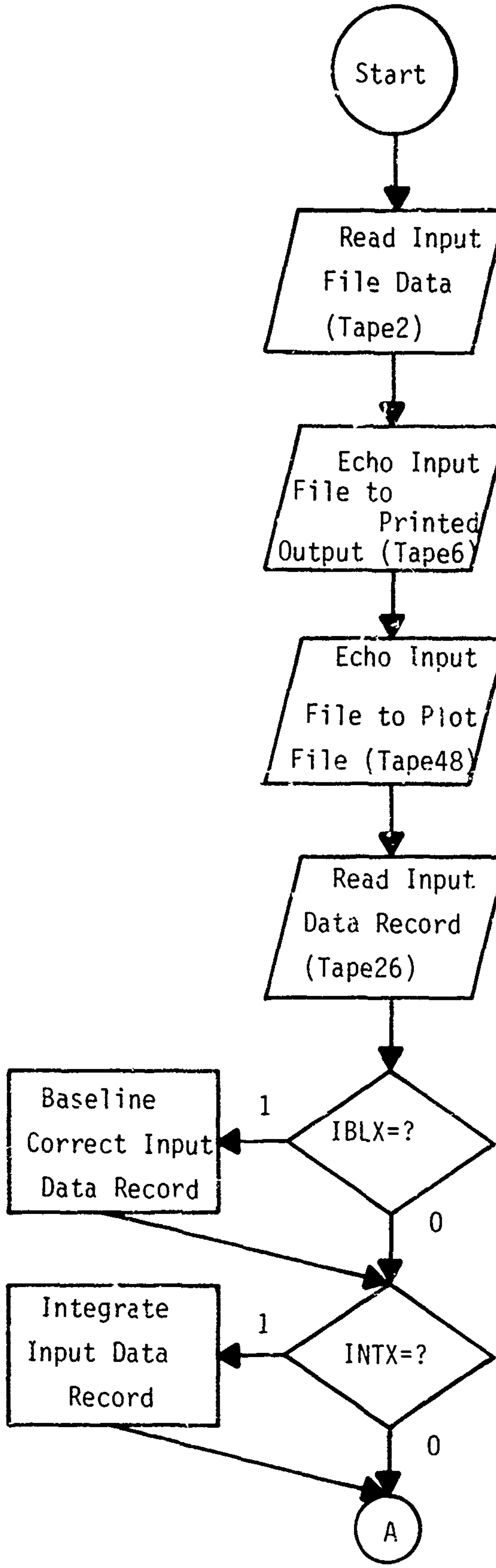


Figure 33. Program FREQRES flow chart.

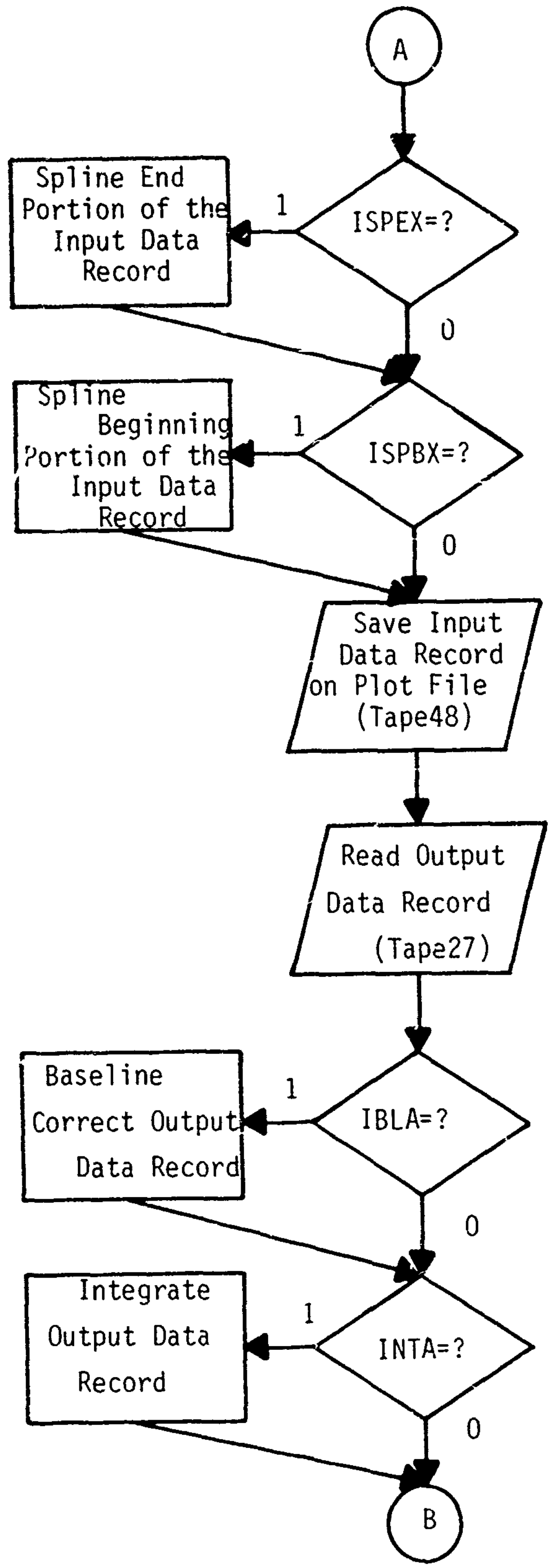


Figure 33. Program FREQRES flow chart (Continued).

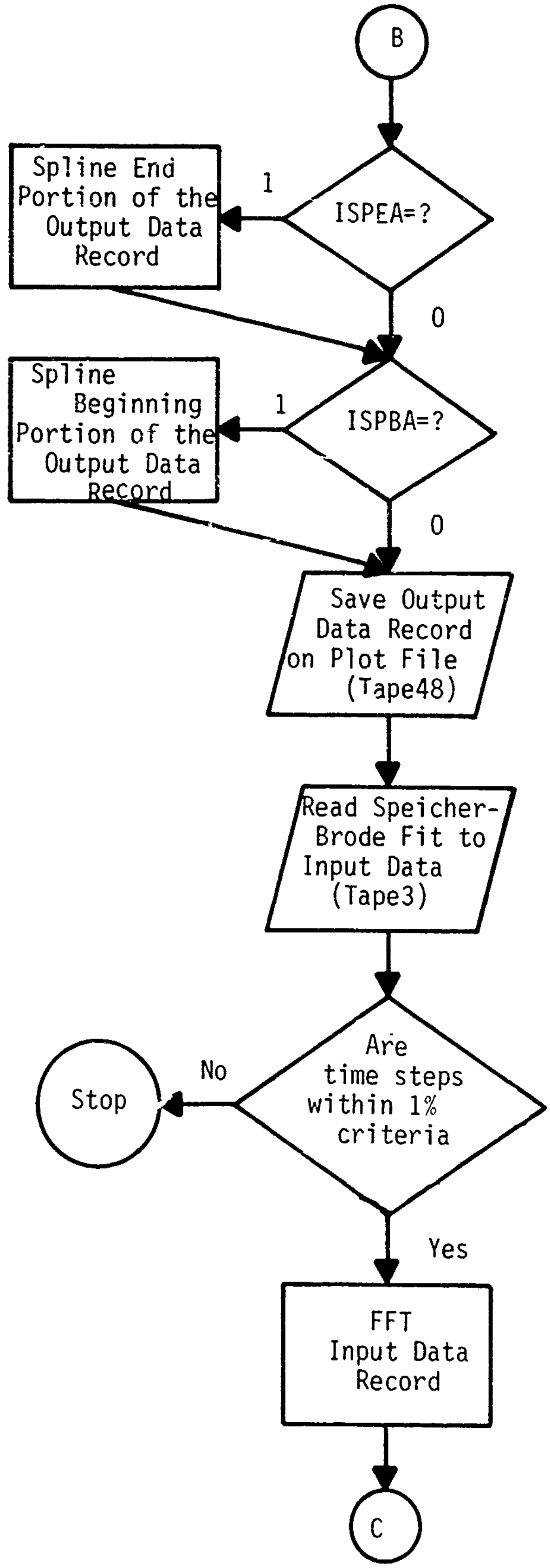


Figure 33. Program FREQRES flow chart (Continued).

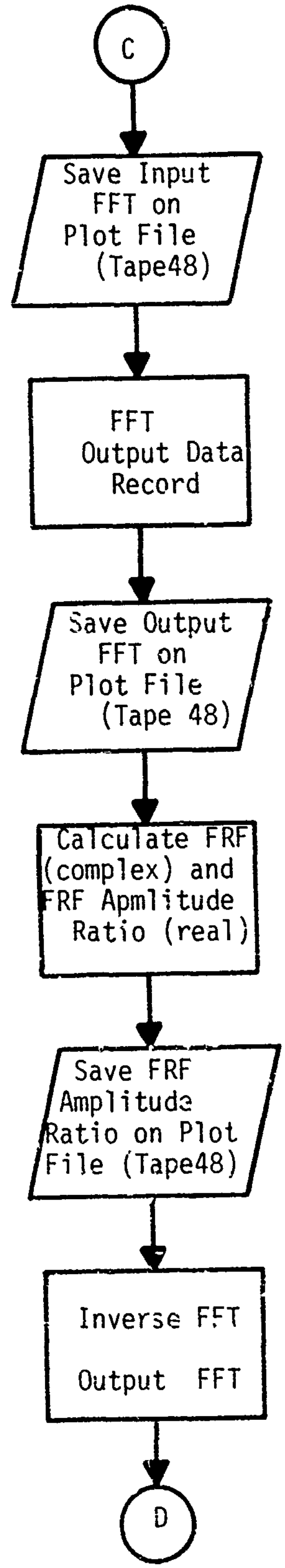


Figure 33. Program FREQRES flow chart (Continued).

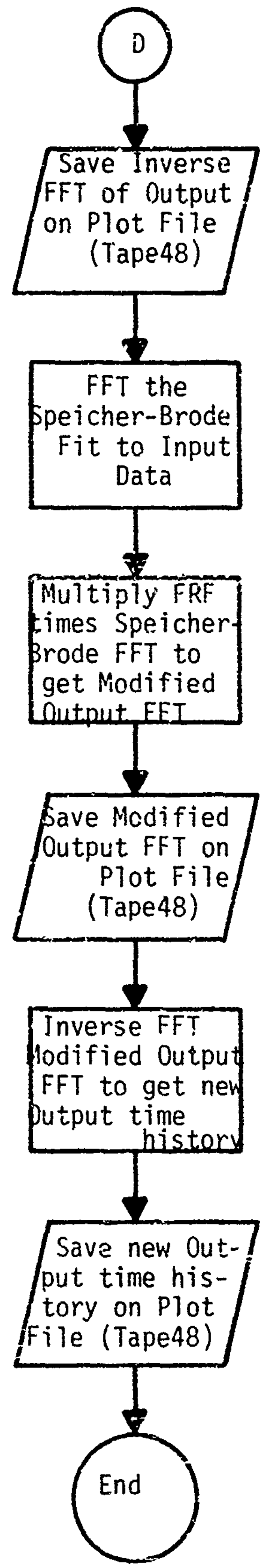


Figure 33. Program FREQRES flow chart (Concluded).

Table 1. Descriptions of Example Test Data.

Record Number	Description
2	HEST pressure on the test article
4	HEST pressure on soil
5	Vertical soil stress at 0.5' depth
6	Vertical soil stress at 0.5' depth
7	Vertical soil stress at 5.21' depth
8	Vertical structure acceleration at 0.83' depth
9	Vertical structure acceleration at 3.28' depth
10	Vertical soil acceleration at 5.21' depth
11	Vertical soil acceleration at 12.21' depth
12	Vertical structure strain at 1.29' depth
13	Vertical structure strain at 1.29' depth
14	Vertical structure strain at 3.33' depth
15	Vertical structure strain at 5.21' depth
16	Vertical structure strain at 12.21' depth
17	Vertical structure strain at 18.71' depth
18	Structure hoop strain at 1.29' depth
19	Structure hoop strain at 5.29' depth
20	Structure hoop strain at 12.21' depth

Table 2. FREQRES input file variable list and descriptions.

CARD	COLUMN	FORMAT	VARIABLE	DESCRIPTION
1	1-5	I5	NEPTS	NO. OF POINTS TO BE READ FROM TAPE
	6-10	I5	NSKIP	SKIP INTERVAL (DEFAULT=1, ALL POINTS FROM TAPE ARE SAVED)
	11-20	E10.3	TFAC	TIME CONVERSION FACTOR (DEFAULT=1.0)
	21-30	E10.3	XFAC	INPUT DATA CONV. FACTOR (DEFAULT=1.0)
	31-40	E10.3	AFAC	OUTPUT DATA CONV. FACTOR (DEFAULT=1.0)
2	1-5	I5	ISPBX	0: NO SPLINE PERFORMED ON BEGINNING OF INPUT DATA 1: BEGINNING OF INPUT DATA WILL BE SPLINED (DEFAULT=0)
	6-15	E10.3	TSPBX	IF ISPBX=1, A SPLINE IS PERFORMED AT THIS TIME BACK TO TIME ZERO (DEFAULT IS 0.0 WHICH MEANS NO SPLINE IS DONE)
	16-20	I5	ISPEX	0 NO SPLINE PERFORMED ON END OF INPUT DATA 1: END OF INPUT DATA WILL BE SPLINED (DEFAULT=0)
	21-30	E10.3	TSPEX	IF ISPEX=1, TIME AT WHICH SPLINE BEGINS FOR INPUT DATA (DEFAULT IS 85% OF TTOT)
	31-35	I5	ISPBA	0: NO SPLINE PERFORMED ON BEGINNING OF OUTPUT DATA 1: BEGINNING OF OUTPUT DATA WILL BE SPLINED (DEFAULT=0)
	36-45	E10.3	TSPBA	IF ISPBA=1, A SPLINE IS PERFORMED AT THIS TIME BACK TO TIME ZERO (DEFAULT IS 0.0 WHICH MEANS NO SPLINE IS DONE)
	46-50	I5	ISPEA	0: NO SPLINE PERFORMED ON END OF OUTPUT DATA 1: END OF OUTPUT DATA WILL BE SPLINED (DEFAULT=0)
	51-60	E10.3	TSPEA	IF ISPEA=1, TIME AT WHICH SPLINE BEGINS FOR OUTPUT DATA (DEFAULT IS 85% OF TTOT)
3	1-5	I5	IBLX	INPUT DATA BASELINE CORRECTION TRIGGER 0: NO BASELINE CORRECTION 1: BASELINE CORRECTION WITH THE FOLLOWING PARAMETERS (DEFAULT=0)
	6-15	E10.3	DELPX	CORRECTION ADDED TO INPUT DATA VALUES AFTER TIME SBX. IF EBX AND SBX ARE EQUAL THEN THE FULL VALUE OF DELPX IS ADDED AT ALL TIMES AFTER SBX. IF EBX IS GREATER THAN SBX THEN THE PLOT IS ROTATED ABOUT THE POINT DEFINED AT SBX BY THE AMOUNT DELPX AT TIME EBX.
	16-25	E10.3	SBX	START TIME FOR BASELINE CORRECTION (PLOT ROTATION POINT IF EBX > SBX)
	26-35	E10.3	EBX	END TIME FOR BASELINE CORRECTION
	36-40	I5	INTX	INPUT DATA INTEGRATION TRIGGER 0: NO INTEGRATION 1: INTEGRATE INPUT DATA

Table 2. FREQRES input file variable list and descriptions (Concluded).

4	1-5	I5	IBLA	OUTPUT DATA BASELINE CORRECTION TRIGGER 0: NO BASELINE CORRECTION 1: BASELINE CORRECTION WITH THE FOLLOWING PARAMETERS (DEFAULT=0)
	6-15	E10.3	DELPA	CORRECTION ADDED TO OUTPUT DATA VALUES AFTER TIME SBA. IF EBA AND SBA ARE EQUAL THEN THE FULL VALUE OF DELPA IS ADDED AT ALL TIMES AFTER SBA. IF EBA IS GREATER THAN SBA THEN THE PLOT IS ROTATED ABOUT THE POINT DEFINED AT SBA BY THE AMOUNT DELPA AT TIME EBA.
	16-25	E10.3	SBA	START TIME FOR BASELINE CORRECTION (PLOT ROTATION POINT IF EBA > SBA)
	26-35	E10.3	EBA	END TIME FOR BASELINE CORRECTION
	36-40	I5	INTA	OUTPUT DATA INTEGRATION TRIGGER 0: NO INTEGRATION 1: INTEGRATE OUTPUT DATA

NOTE: ALL OF THE FOLLOWING LABELS SHOULD BE CENTERED WITHIN THE FIRST 30 COLUMNS OF EACH LINE OF THE INPUT FILE.

5	1-40	4A10	ITX	INPUT DATA X-AXIS LABEL; EXAMPLE: TIME (SEC)
6	1-40	4A10	ITY	INPUT DATA Y-AXIS LABEL; EX: PRESSURE (PSI)
7	1-40	4A10	ITX	OUTPUT DATA X-AXIS LABEL; EX: TIME (SEC)
8	1-40	4A10	ITY	OUTPUT DATA Y-AXIS LABEL; EX: STRAIN (IN/IN)
9	1-40	4A10	ITX	INPUT DATA FOURIER AMP. SPEC. X-AXIS LABEL; EX: FREQUENCY (HZ)
10	1-40	4A10	ITY	INPUT DATA FOURIER AMP. SPEC. Y-AXIS LABEL; EX: AMPLITUDE (PSI-SEC)
11	1-40	4A10	ITX	OUTPUT DATA FOURIER AMP. SPEC. X-AXIS LABEL; EX: FREQUENCY (HZ)
12	1-40	4A10	ITY	OUTPUT DATA FOURIER AMP. SPEC. Y-AXIS LABEL; EX: AMPLITUDE (SEC)
13	1-40	4A10	ITX	FREQUENCY RESPONSE FUNCTION X-AXIS LABEL; EX: FREQUENCY (HZ)
14	1-40	4A10	ITY	FREQUENCY RESPONSE FUNCTION Y-AXIS LABEL; EX: FFTX/FFTA
15	1-40	4A10	ITX	BRODE OUTPUT RESPONSE X-AXIS LABEL; EX. TIME (SEC)
16	1-40	4A10	ITY	BRODE OUTPUT RESPONSE Y-AXIS LABEL; EX: STRAIN (IN/IN)

Table 3. Sample output listing from a FREQRES calculation.

```
   FREQRES OUTPUT LISTING

THE NUMBER OF POINTS READ FROM THE DATA RECORD TAPES IS  9970 WITH A SKIP OF 27 CONSIDERED FOR ANALYSIS

   TIME CONVERSION FACTOR      =     .100E+01
   INPUT DATA CONV. FACTOR     =     .100E+01
   OUTPUT DATA CONV. FACTOR    =     .100E+01

BEGINNING PORTION OF INPUT DATA SPLINED FROM TIME EQUAL 0.0 TO TIME EQUAL   .260E-02

FINAL 15% OF INPUT DATA SPLINED TO ZERO

BEGINNING PORTION OF OUTPUT DATA SPLINED FROM TIME EQUAL 0.0 TO TIME EQUAL   .300E-02

FINAL 15% OF OUTPUT DATA SPLINED TO ZERO

********************************************************************************


VERY IMPORTANT NOTICE:
   NBPTS FOR THE SPEICHER-BRODE FIT FROM FOURFIT =   392
   MUST BE EQUAL TO NPT FROM THIS PROGRAM        =   369
   IF NBPTS AND NPT ARE NOT EQUAL, THIS PROGRAM WILL
   TRUNCATE ONE OF THEM TO MAKE THEM EQUAL.

  DTBP FOR THE SPEICHER-BRODE FIT FROM FOURFIT =  .13372120E-03
  MUST BE VERY CLOSE TO DTD FROM THIS PROGRAM  =  .13500000E-03
   IF THEY ARE NOT CLOSE, THIS PROGRAM WILL STOP


********************************************************************************


OUTPUT RECORD TOTAL IMPULSE =     .649781E+02
FIRST POINT OF OUTPUT FFT   =     .648020E+02
OUTPUT INVERSE FFT OFFSET   =     .129430E+04
```

Table 4. Input file variable specifications for each data record.

Record	NSKIP	TFAC	XFAC	AFAC	Beginning Spike Prior to	Final 15 Percent Splined to Zero	Constant* BLC Perform After	Amount of BLC	Integration
2	35	1.0	1.0	--	2.7 ms	X			
4	27	1.0	1.0	--	2.6 ms	X			
5	27	1.0	--	1.0	3.0 ms	X			
6	27	1.0	--	1.0	3.0 ms	X			
7	27	1.0	--	1.0	6.0 ms	X			
8	35	1.0	--	32.2	2.7 ms	X	2.8 ms	-10098 ft/s^2	X
9	35	1.0	--	32.2	2.7 ms	X			X
10	27	1.0	--	32.2	5.5 ms	X			X
11	27	1.0	--	32.2	9.1 ms	X	9.2 ms	1290 ft/s^2	X
12	35	1.0	--	-1.0	2.8 ms	X			
13	35	1.0	--	-1.0	2.8 ms	X			
14	35	1.0	--	-1.0	2.8 ms	X			
15	35	1.0	--	-1.0	2.8 ms	X			
16	35	1.0	--	-1.0	3.2 ms	X			
17	35	1.0	--	-1.0	3.2 ms	X			
18	35	1.0	--	-1.0	2.6 ms	X			
19	35	1.0	--	-1.0	3.0 ms	X			
20	35	1.0	--	-1.0	3.1 ms	X			

* BLC = Base Line Correction

Table 5. Summary of the total impulse, first FFT value, and inverse FFT offset for the test data.

Record Number	Total Impulse	First FFT Value	Inverse FFT Offset
4	24.93 psi-sec	24.87 psi-sec	516 psi
5	64.98 psi-sec	64.80 psi-sec	1294 psi
6	47.34 psi-sec	47.22 psi-sec	947 psi
7	33.74 psi-sec	33.65 psi-sec	676 psi
8	.5192 ft	.5174 ft	10.4 ft/s
9	.7249 ft	.7223 ft	14.5 ft/s
10	.7842 ft	.7821 ft	15.7 ft/s
11	.4031 ft	.4020 ft	8.07 ft/s
12	.1170 micro sec	.1166 micro sec	-.39 micro strain
13	.6474 micro sec	.6451 micro sec	10.2 micro strain
14	-14.46 micro sec	14.40 micro sec	-288 micro strain
15	8.581 micro sec	8.551 micro sec	173 micro strain
16	48.47 micro sec	48.30 micro sec	968 micro strain
17	5.014 micro sec	4.997 micro sec	98.4 micro strain
18	24.80 micro sec	24.71 micro sec	496 micro strain
19	10.27 micro sec	10.23 micro sec	205 micro strain
20	-4.586 micro sec	4.570 micro sec	-92.1 micro strain

Table 6. FREQRES input files.

Input File	Description
TAPE2	Input file for input variable specification as described in Section 3.1
TAPE3	Speicher-Brode "best-fit" waveform obtained from TAPE49 of FOURFIT calculation
TAPE26	Input data record digitized time history
TAPE27	Output data record digitized time history

Table 7. FREQRES output files.

Output File	Description
TAPE6	Printed output
TAPE48	Plot file

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